NPS ARCHIVE
1964
MCMANUS, J.

THERMAL STRESS ANALYSIS OF PRESSURE VESSELS WITH CYLINDRICAL SKIRT SUPPORTS

JAMES P. McMANUS

Library
U. S. Naval Postgraduate School
Monterey, California

THERMAL STRESS ANALYSIS OF PRESSURE VESSELS WITH CYLINDRICAL SKIRT SUPPORTS

* * * * *

James P. McManus

THERMAL STRESS ANALYSIS OF PRESSURE VESSELS WITH CYLINDRICAL SKIRT SUPPORTS

by

James P. McManus
Lieutenant, United States Naval Reserve

Submitted in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE
IN
MECHANICAL ENGINEERING

United States Naval Postgraduate School
Monterey, California

1 9 6 4

NPS ARCHIVE
1964
MCMANUS, J

Library
U. S. Naval Postgraduate School
Monterey, California
U. S. Naval Postgraduate School
Monterey, California

THERMAL STRESS ANALYSIS OF PRESSURE VESSELS WITH CYLINDRICAL SKIRT SUPPORTS

by

James P. McManus

This work is accepted as fulfilling
the thesis requirements for the degree of
MASTER OF SCIENCE
IN
MECHANICAL ENGINEERING
from the
United States Naval Postgraduate School

ABSTRACT

A method is described for determination of stresses near the circumferential junction of shell, head, and skirt of a pressure vessel subjected to mechanical and thermal loadings. Considerable latitude is permitted for variation in geometrical, mechanical, and loading characteristics; however, it is presumed that there is complete symmetry about the axis of the vessel. A digital computer program is appended to facilitate solution of the problem.

ACKNOWLEDGEMENT

The writer extends his thanks to Dr. John E. Brock, the faculty advisor for this thesis. Dr. Brock's helpful advice and criticism have made working on the thesis a very rewarding experience.

TABLE OF CONTENTS

Section	Title	Page
1.	Introduction	1
2.	Theory	7
3.	Method	16
4.	Digital Computer Program	34
5.	Conclusion	38
6.	Bibliography	40
7.	Appendix A - Instructions for Use of Program Skirt	A1
8.	Appendix B - Listing of Program Skirt and Logical Flow Chart	B1
9.	Appendix C - Sample Problems	C1

1. Introduction

The chemical and petroleum industries have constructed many pressure vessels with vertical axes and cylindrical skirt supports. Some of these vessels contain fluids at temperatures as high as 1000°F with resultant high heat flows through the skirt support.[5]* These heat flows, and the thermal stresses resulting, give rise to the "Hot Skirt Problem" which is here generalized to that of determining the stress distribution near the junction of shell, head, and supporting skirt of a vertical pressure vessel, resulting from any combination of the following loadings:

1. Changes in temperature proceeding axially along any of these elements (shell, head, skirt).
2. Changes in temperature (assumed to vary linearly) through the thickness of an element.
3. Internal pressure in the shell and head but not in the skirt.
4. An additional axial loading on any or all of the elements. (Could result from the dead weight of one of the elements.)
5. A moment applied to the junction of the three elements by agencies external to the elements.
6. A radially outward distributed loading applied to the junction by agencies external to the elements.

*Numbers in brackets refer to bibliography, page 40.

Throughout it is assumed that the three elements are joined on a common circumference, that they and their loadings are axially symmetric, that the material of the elements remains elastic, and that the structure always remains stable and all deformations are "small". It is also assumed that the walls of the elements are "thin".

The theory of thin axisymmetric cylinders (Section 2) shows that all except axial loadings applied a sufficient distance from the end of the cylinder (i.e., junction end), influence that end very slightly. Axial loadings however are transmitted without change. Also one may consider such shell configurations as cones, ellipsoids, etc., as if they were cylinders for purposes of calculating their reactions close to the junction end due to influences at that end, providing such shells are reasonably "deep".* Only a finite length of the shell need be considered since any nonaxial loading has negligible effect upon the junction end if it is remote enough. This nonaxial loading may therefore be taken to be zero, which suggests a finite length with the remote end free.

Thus the present solution involves three finite cylinders, joined together at their common junction ends. To be as general as possible, this solution allows the material properties of the shells to vary axially and even

*See footnote, page 127, Ref. 3 Part II.

the radius and thickness to vary "slowly". The variance of radius and thickness must be kept within reasonable limits to assure the desired accuracy in the solutions, since terms resulting from axial derivatives of these quantities are not included.

Each cylinder is dealt with in turn, performing the following sequence of calculations:

1. The moment, shear, slope (belling), and radial deflection are found and recorded for each of n (a preselected integer) points along the disconnected finite cylinder, resulting from the application of Loads 1 through 4 as previously listed.
2. The same quantities are calculated and recorded, resulting from a unit moment (unit moment per unit circumference) applied to the junction end of the cylinder.
3. The same quantities are calculated and recorded, resulting from a unit shear (unit radial load per unit circumference) applied to the junction end of the cylinder.

Equations of statics may be written relating the end moments and shears to the externally applied loads numbers 5 and 6. Using the junction end slopes and radial

deformations found in Calculations 1, 2, and 3, equations of slope and displacement continuity may be written relating again the end moments and shears. These relations result in six linear equations with six unknowns (the three end moments and three end shears) which may be solved for the junction end moment and shear on each cylinder.

When the end conditions are known for an element, the deflection, moment, and shear along the length of the element may be calculated using the results of calculations 1, 2, and 3, which have been retained. The stresses are then calculated using the deflection and moment.

Two methods are presented for handling internal pressure. The first considers pressure loading at the outset as an input into Calculation 1. This is permissible if the local geometry is essentially that of a cylinder. If, however, either the shell or head is not cylindrical in shape at the junction, all loads but pressure are included in Calculation 1. The effects of pressure are computed separately for shell and head using membrane theory. The resultant end deflections due to pressure are included in the continuity equations and the membrane pressure stresses are added to the stresses calculated from all other loadings (including the bending stress caused by dissimiliar deflections due to pressure).

A finite difference iterative procedure is used to solve the fourth order differential equation presented in Section 3 and is the "heart" of the solution. Essentially an assumption of the radial deformation of the cylinder is made and an integration is performed to find a new shape. To assist convergence, an averaging process is used but for some shells convergence may still be difficult to attain.

The original goal was to develop a method which could be easily performed on a desk calculator in a reasonable length of time. Due to the difficulty in attaining convergence this goal has only been partially met. If one had a problem with cylinders of constant parameters so that the numerical solution need only be performed for Calculation 1, with an analytical solution available for Calculations 2 and 3, a hand solution might be feasible. To solve more complicated problems a digital computer program has been written in Fortran language and is listed in Appendix B. This program allows one to consider shells and loadings, the solutions for which would take a prohibitive amount of time by hand.

Three cylinders were assumed to be present in developing the method and the computer program. However if one wishes to consider a vessel of but two abutting elements, one may choose a very small length for the unwanted cylinder,

thereby effectively eliminating its influence.

Some previous work has been published on a hot skirt problem. Weil and Murphy [1] have developed a solution adapting the equations of the analytical solution of a beam on an elastic foundation to a cylinder. However these equations require a constant "beam" or constant cross section cylinder. This restricts the problem to a constant axial thermal gradient, and constant temperature difference across the wall thickness. These restrictions are severe and limit greatly the usefulness of their solution.

2. Theory

Consider a small element cut from a cylinder with dimensions dx, ad , and t in the x, y, and z directions. The cylinder is of radius a, and has a wall thickness t. Figure 1 illustrates the element.

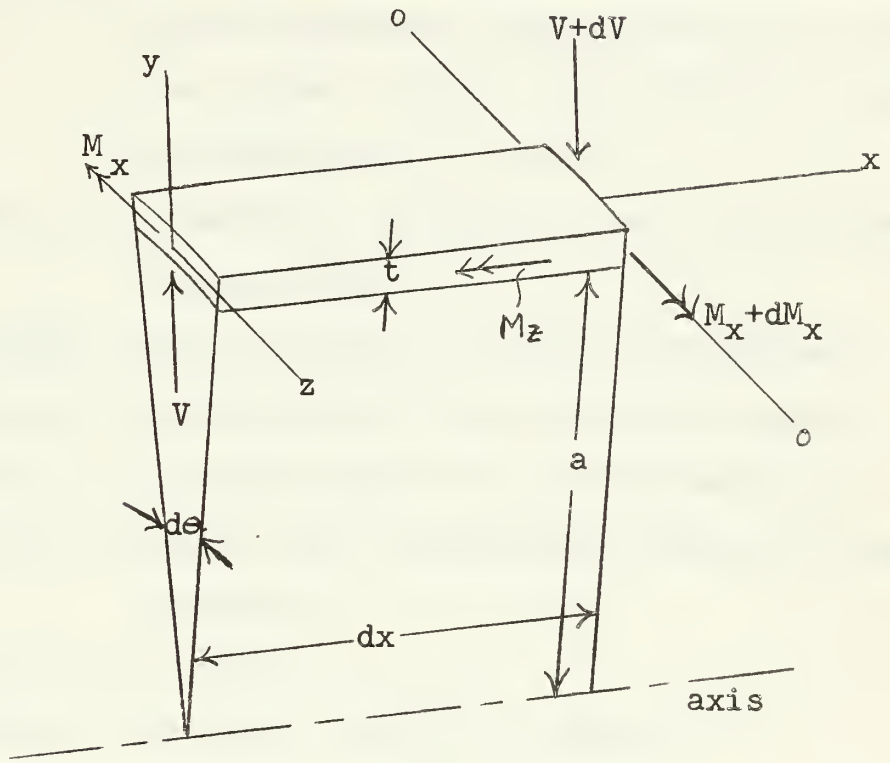


Figure 1. Element Cut from Cylinder

The following symbols will be used in this section:

a = radius of cylinder

D = $Et^3/12(1-\mu^2)$ = longitudinal stiffness of a unit width of element, (also called plate flexural rigidity.)

d = infinitesimal central angle.

E = Young's Modulus.

e_{mx} and e_{mz} = centerline extensional strain in x and z directions respectively due to all but thermal causes.

e_{bx} and e_{bz} = bending strain on inner wall surface in x and z directions respectively due to all but thermal causes; and positive as indicated in equations (5) and (6).

e_x and e_z = extensional strain in x and z directions respectively.

M_x = moment (as illustrated) per unit circumference.

M_z = moment (as illustrated) per unit axial length.

P = $ap/2 + P^*$ = axial force per unit circumference.

P^* = axial force per unit circumference from all causes but pressure.

p = internal pressure.

s = radial deflection. (Positive outward.)

t = wall thickness.

T = temperature at centerline of wall.

ΔT = inner wall temperature minus outer wall temperature.

V = radial force per unit circumference. (Positive as shown.)

x, y, and z = cartesian coordinates as shown in Figure 1.

α = coefficient of linear thermal expansion.

χ_x = curvature in x, y plane.

ρ_x = radius of curvature in x, y plane.

σ_x and σ_z = axial and circumferential tensile stresses, respectively.

μ = Poisson's ratio.

For axial equilibrium:

$$(1) \quad P = \int_{-t/2}^{t/2} \sigma_x dy$$

For equilibrium in the y direction:

$$pad\theta dx + ad\theta V = ad\theta(V+dV) + d\theta dx \int_{-t/2}^{t/2} \sigma_z dy$$

This reduces to:

$$(2) \quad \frac{dV}{dx} = p - \frac{1}{a} \int_{-t/2}^{t/2} \sigma_z dy.$$

Taking moments about axis o-o:

$$ad\theta(M_x + Vdx) + (pad\theta dx)\frac{dx}{2} = (M_x + dM_x)ad\theta +$$

$$(d\theta dx \int_{-t/2}^{t/2} \sigma_z dy)\ \frac{dx}{2}$$

which reduces to:

$$(3) \quad \frac{dM_x}{dx} = V.$$

Also from elementary statics:

$$(4a,b) \quad M_x = -\int_{-t/2}^{t/2} \sigma_x y dy \text{ and } M_z = -\int_{-t/2}^{t/2} \sigma_z y dy.$$

Assuming the longitudinal strain is linear through the wall:

$$(5) \quad e_x = e_{mx} - \frac{2y}{t} e_{bx} - \frac{\alpha y}{t} \Delta T + \alpha T$$

Assuming circumferential strain is linear through the wall:

$$(6) \quad e_z = e_{mz} - \frac{2y}{t} e_{bz} - \frac{\alpha y}{t} \Delta T + \alpha T$$

These assumptions are reasonable if $t \ll a$. Otherwise the distribution may be nonlinear. Thus, for example, the stress distribution due to internal pressure in a thick cylinder is hyperbolic (Lame' Solution).

Figure 2 shows the cross section of a piece cut from the cylinder wall of width $ad\theta$ and length dx. The strains are greatly magnified for illustrative purposes. From similar sectors:

$$\chi_x dx = dx/\rho_x \cong (e_{bx} + \alpha \Delta T/2)dx/(t/2).$$

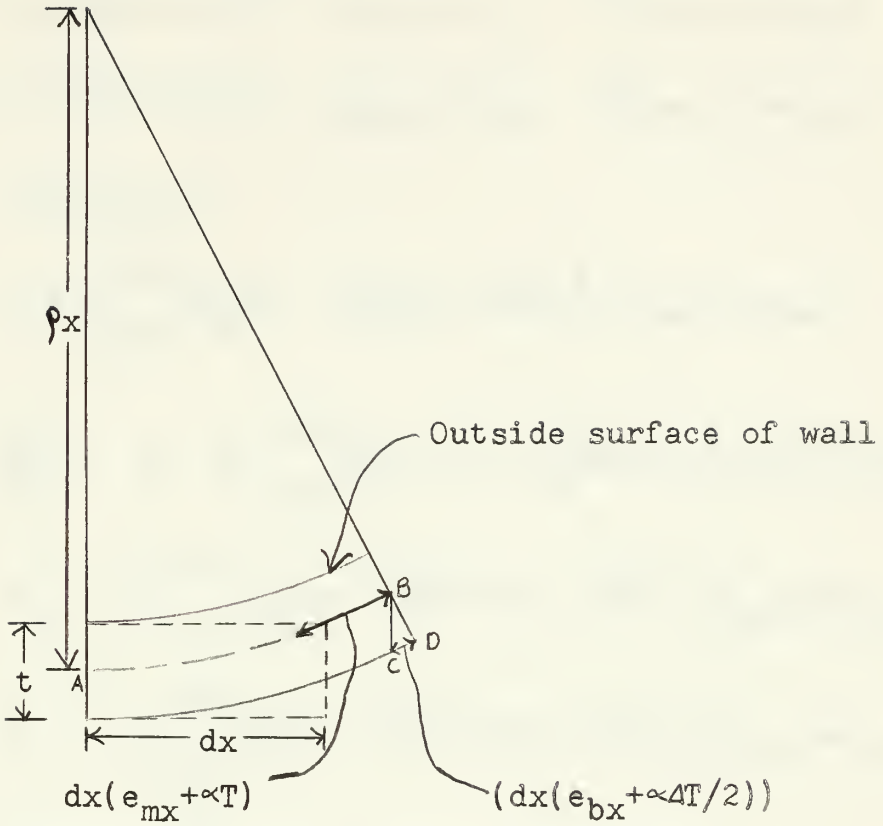


Figure 2 Cross Section of Cylinder Wall

Presuming that $\frac{ds}{dx} \ll 1$, $\chi_x \approx \frac{d^2s}{dx^2}$. Therefore:

(7) $\frac{d^2s}{dx^2} = (2e_{bx} + \propto \Delta T)/t.$

(8) $e_z = s/(a+y) \approx s/a.$ (Here again we assume $t \ll a.$)

Comparing (6) and (8), and equating coefficients of like powers of y:

(9) $e_{bz} = -\propto \Delta T/2$

(10) $e_{mz} = s/a - \propto T.$

The fundamental stress-strain relations are:

(11) $\sigma_x = [E/(1-\mu^2)] \quad [(e_{mx} + \mu e_{mz}) - \frac{2y}{t}(e_{bx} + \mu e_{bz})]$

(12) $\sigma_z = [E/(1-\mu^2)] \quad [(e_{mz} + \mu e_{mx}) - \frac{2y}{t}(e_{bz} + \mu e_{bx})]$

Therefore:

(13) $P = \int_{-t/2}^{t/2} \sigma_x dy = [Et/(1-\mu^2)] \quad [(e_{mx} + \mu e_{mz})]$

(14) $\frac{dV}{dx} = p - \frac{1}{a}\int_{-t/2}^{t/2} \sigma_z dy = p - [(Et/a)/(1-\mu^2)] \quad [(e_{mz} + \mu e_{mx})]$

(15) $M_x = -\int_{-t/2}^{t/2} \sigma_x y dy = [Et^2/6(1-\mu^2)] \quad [(e_{bx} + \mu e_{bz})]$

(16) $M_z = -\int_{-t/2}^{t/2} \sigma_z y dy = [Et^2/6(1-\mu^2)] \quad [(e_{bz} + \mu e_{bx})]$

Combining (7), (9), and (15), we get:

(17) $\frac{d^2s}{dx^2} = \frac{M_x}{D} + \frac{(1+\mu)\alpha \Delta T}{t}$

Eliminating e_{mx} from (13) and (14):

(18) $\frac{dV}{dx} = p - \frac{\mu P}{a} - \frac{Ete_{mz}}{a}$

Substituting (10):

(19) $\frac{dV}{dx} = p - \frac{\mu P}{a} + \frac{Et\alpha T}{a} - \frac{Ets}{a^2}$.

From (15) and (9):

(20) $e_{bx} = \frac{6(1-\mu^2)M_x}{Et^2} + \frac{\mu \alpha \Delta T}{2}$,

and from (13) and (10):

$$(21)\quad e_{mx} = \frac{(1-\mu^2)\,P}{Et} - \frac{\mu s}{a} + \mu\alpha T.$$

Summarizing:

$$(22a)\quad \frac{dV}{dx} = p + \frac{Et\alpha T}{a} - \frac{\mu P}{a} - \frac{Ets}{a^2}$$

$$(22b)\quad \frac{dM_x}{dx} = V$$

$$(22c)\quad \frac{d^2s}{dx^2} = \frac{M_x}{D} + \frac{(1-\mu)\alpha\Delta T}{t}.$$

If it is assumed that $T=P=\Delta T=0$, and that a, E, μ, and t are constants, equations (22) reduce to:

$$(23)\quad D\frac{d^4s}{dx^4} = \frac{-Ets}{a^2}.$$

The solution to (23) assuming a semi-infinite cylinder, is:

$$(24)\quad s = \frac{e^{-\beta x}}{2\beta^3 D}\left[V_1\cos\beta x + \beta M_{x1}(\cos\beta x - \sin\beta x)\right]$$

where V_1 and M_{x1} are the end loadings, and $\beta = \sqrt[4]{\frac{Et}{4a^2D}}$.

M_x then equals $D\frac{d^2s}{dx^2}$.

After M_x and s have been determined either by numerical solution of (22) or by using (24), the stresses in the

and from (13) and (10):

$$(21)\quad e_{mx} = \frac{(1-\mu^2)\,P}{Et} - \frac{\mu s}{a} + \mu\alpha T.$$

Summarizing:

$$(22a)\quad \frac{dV}{dx} = p + \frac{Et\alpha T}{a} - \frac{\mu P}{a} - \frac{Ets}{a^2}$$

$$(22b)\quad \frac{dM_x}{dx} = V$$

$$(22c)\quad \frac{d^2s}{dx^2} = \frac{M_x}{D} + \frac{(1-\mu)\alpha\Delta T}{t}.$$

If it is assumed that $T=P=\Delta T=0$, and that a, E, μ, and t are constants, equations (22) reduce to:

$$(23)\quad D\frac{d^4s}{dx^4} = \frac{-Ets}{a^2}.$$

The solution to (23) assuming a semi-infinite cylinder, is:

$$(24)\quad s = \frac{e^{-\beta x}}{2\beta^3 D}\left[V_1\cos\beta x + \beta M_{x1}(\cos\beta x - \sin\beta x)\right]$$

where V_1 and M_{x1} are the end loadings, and $\beta = \sqrt[4]{\frac{Et}{4a^2D}}$.

M_x then equals $D\frac{d^2s}{dx^2}$.

After M_x and s have been determined either by numerical solution of (22) or by using (24), the stresses in the

cylinder may be determined with equations (9),(10),(20), (21),(11), and (12). The results are:

$$\sigma_{x\ \text{inner}} = \frac{P}{t} + \frac{6M_x}{t^2}$$

$$\sigma_{x\ \text{outer}} = \frac{P}{t} - \frac{6M_x}{t^2} \tag{25}$$

$$\sigma_{z\ \text{inner}} = \frac{Es}{a} - E\alpha T + \frac{\mu P}{t} - \frac{E\alpha\Delta T}{2} + \frac{6\mu M_x}{t^2}$$

$$\sigma_{z\ \text{outer}} = \frac{Es}{a} - E\alpha T + \frac{\mu P}{t} + \frac{E\alpha\Delta T}{2} - \frac{6\mu M_x}{t^2} \tag{26}$$

A single equivalent stress is frequently used as a basis of assessing the severity of loading on a structure in which the state of stress is not a simple uniaxial stress. The equivalent stress employed here is that of the distortion energy theory (equivalently, of the octahedral shearing stress theory). If the principal stresses are σ_x, σ_z and zero, as they are at the outside of the cylinders, the equivalent stress is:

$$\sigma_d = \sqrt{\sigma_x^2 - \sigma_x\sigma_z + \sigma_z^2}\ .$$

On the interior surface, if a pressure p is acting, the third principal stress is -p rather than zero. However, the same formula is used since σ_x and σ_z are at least one or two orders of magnitude greater than p. Thus:

(27) $$\sigma_{d\ \text{outer}} = \sqrt{\sigma^2_{x\ \text{outer}} - (\sigma_x \sigma_z)_{\text{outer}} + \sigma^2_z}$$

and:

(28) $$\sigma_{d\ \text{inner}} = \sqrt{\sigma^2_{x\ \text{inner}} - (\sigma_x \sigma_z)_{\text{inner}} + \sigma^2_z} \quad .$$

3. Method

Figure 3 shows the basic three-cylinder problem that is to be solved, with the numbering convention used, and the sign conventions for the externally applied moment, shear force, radial deflection, and slope when the cylinders are considered jointly.

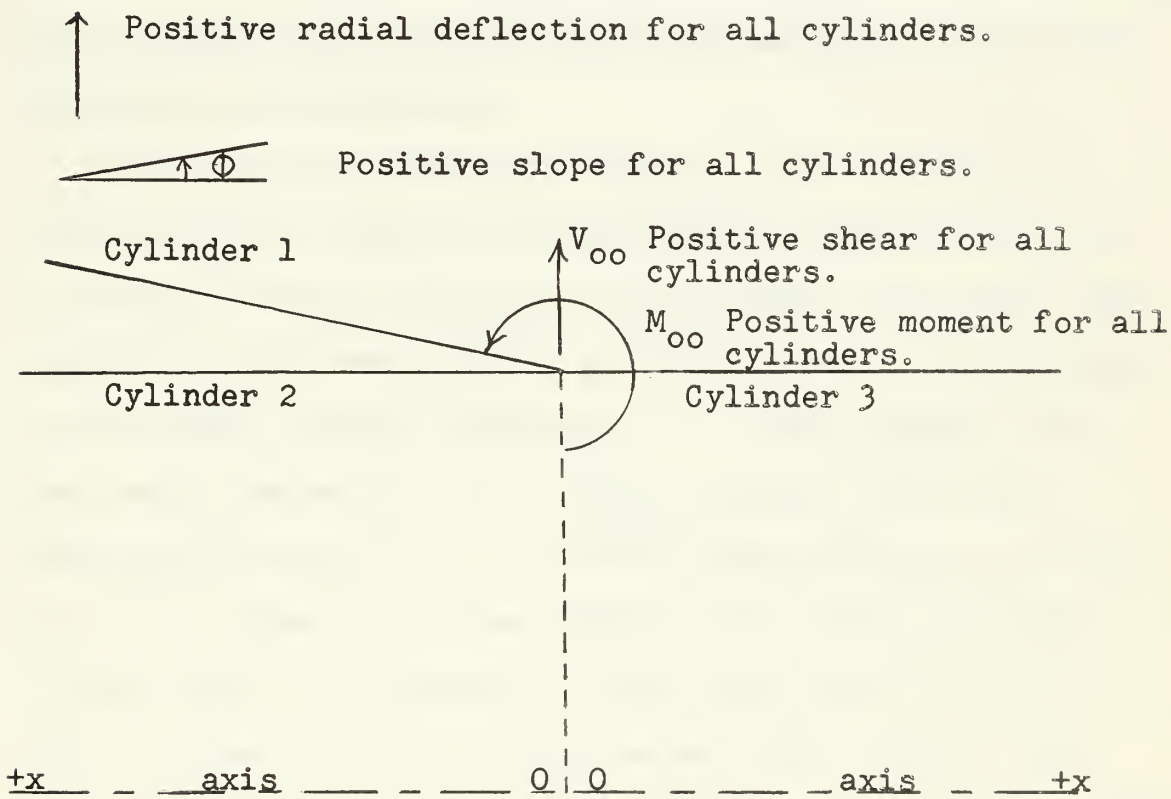


Figure 3. Positions of Three Cylinders and Sign Conventions

The basic procedure to be followed in the solution is to solve equations (22) numerically or (23) analytically to find the reaction of each cylinder to (1) the given loadings, (2) a unit junction end moment*, and (3) a unit junction end shear* when this cylinder is "free" (i.e., disconnected from the junction). The three cylinders are then conceived to be rejoined, and by using the above information along with the equations of statics and continuity, the reactions (i.e., the actual end loadings) of the three cylinders are determined.

The analytic solution of equation (23) is given in equation (24). However in the numerical solution of (22) we choose a finite length for the cylinder. The only load applied to the remote end is a moment equal to that caused by the radial thermal gradient. From equation (24) the radial deflection at $x = 5/\beta$ is about 0.7% of the radial deflection at $x = 0$ for any given loadings applied at $x = 0$. Thus, if L, the length of the finite cylinder, is set equal to $5/\beta$ there is only a small error in the radial deflection at the junction end due to neglecting the loading applied at $x = 5/\beta$ by the portion of the cylinder

*Throughout this thesis "shear" means the radially outward directed load per unit circumferential length and "moment" means moment per unit circumferential (or axial) length.

beyond this point. However an error results if there are nonlinearities close to the remote end. See "Discussion of Results," Appendix C.

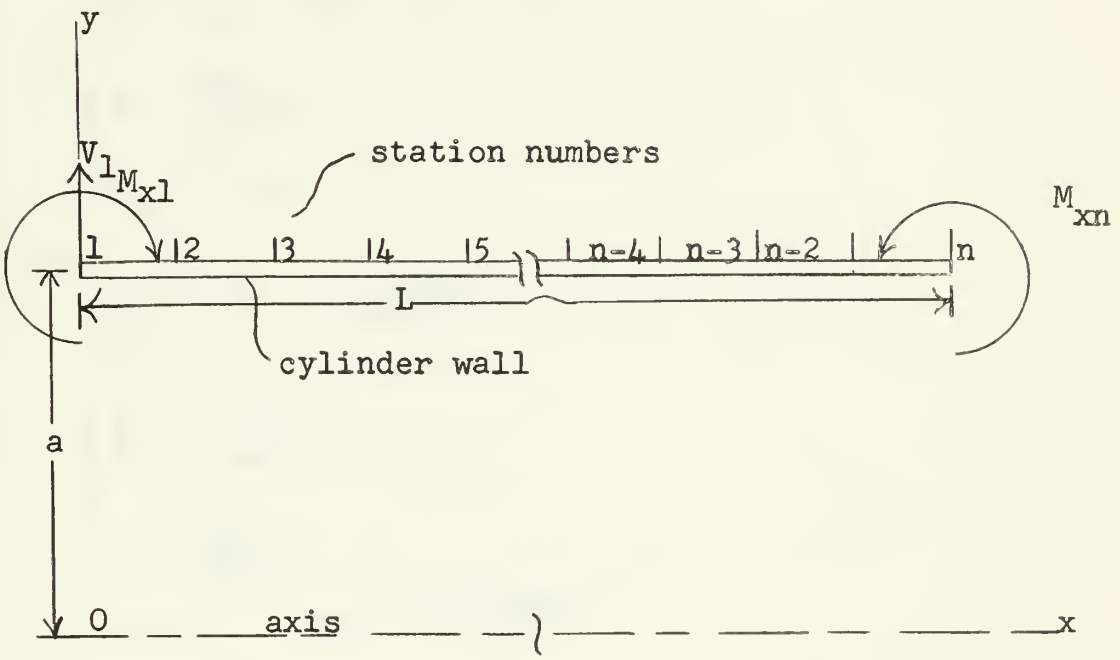


Figure 4. Finite Cylinder Divided into n-1 Increments Showing Loads at Junction and Remote Ends.

The following iterative procedure was developed by John E. Brock, Professor of Mechanical Engineering, U. S. Naval Postgraduate School, Monterey, Calif., and modified by the writer to assist convergence.

Figure 4 shows a cylinder divided into n-1 equal increments with stations 1 through n. (With a modification of the integration method used, the requirement of equal increments could be withdrawn.) At each station, values

of all the parameters of the cylinder and all loadings are assumed known.

Equations (22) may be restated as follows:

$$(29)\quad \begin{cases} \dfrac{dV}{dx} = p + \dfrac{Et\alpha T}{a} - \dfrac{\mu P}{a} - \dfrac{Ets}{a^2} \\ V = \int \dfrac{dV}{dx} dx \\ M_x = \int V dx \\ \dfrac{d^2s}{dx^2} = \dfrac{M_x}{D} + \dfrac{(1+\mu)\alpha \Delta T}{t} \\ \dfrac{ds}{dx} = \int \dfrac{d^2s}{dx^2} dx \\ s = \int \dfrac{ds}{dx} dx \end{cases}$$

Let $M^* = M_x + \dfrac{D(1+\mu)\alpha \Delta T}{t}$

$$(30)\quad M^* = \int V dx + \frac{D(1+\mu)\alpha \Delta T}{t}$$

$$(31)\quad \frac{d^2s}{dx^2} = \frac{M^*}{D}$$

Let $s = A + Bx + f(x)$ where A and B are constants and $f(x)$ is normalized in such a way that $f(0) = f(L) = 0$. Also let $Q = \dfrac{dV}{dx}$. Then from (29), (30), and (31):

$$Q = p + \frac{Et\alpha T}{a} - \frac{\mu P}{a} - \frac{Et}{a^2}\left[A + Bx + f(x)\right]$$

$$(32)\quad = \bar{Q} - A\frac{Et}{a^2} - B\frac{Etx}{a^2} - \frac{Etf(x)}{a^2}$$

where $\bar{Q} = p + \frac{Et\alpha T}{a} - \frac{\mu P}{a}$

$$V = \int Q dx = V_1 + \int_0^x \bar{Q} dx - A\int_0^x \frac{Et}{a^2} dx - B\int_0^x \frac{Et}{a^2} x dx - \int_0^x \frac{Et}{a^2} f(x) dx$$

Let $\frac{Et}{a^2} = k$

$$(33)\quad V = \bar{V} - A\int_0^x k dx - B\int_0^x kx dx - \int_0^x kf(x) dx$$

where $\bar{V} = V_1 + \int_0^x \bar{Q} dx$.

Next

$$M^* = M + \int_0^x \bar{V} dx - A\int_0^x\int_0^x k dx dx - B\int_0^x\int_0^x kx dx dx - \int_0^x\int_0^x kf(x) dx dx + \frac{D(1+\mu)\alpha\Delta T}{t}$$

so that

$$(34)\quad M^* = \bar{M}^* - A\int_0^x\int_0^x k dx dx - B\int_0^x\int_0^x kx dx dx - \int_0^x\int_0^x kf(x) dx dx$$

where $\bar{M}^* = M_{x1} + \int_0^x \bar{V} dx + \frac{D(1+\mu)\alpha\Delta T}{t}$

An initial assumption is made for f(x); conveniently, one may take f(x)=0. Therefore the only unknowns in equations (33) and (34) are A and B.

It is also assumed that at x = L (the remote end of the cylinder), $M_n^* = V_n = 0$. This is a reasonable assumption because as x approaches infinity, with a constant radial thermal gradient, the axial curvature of the cylinder wall approaches zero. L has been chosen long enough so that the conditions at x = L approach those at infinity which allows $M_n^* = V_n = 0$. The two equations and two unknowns are:

$$(35)\quad 0 = \bar{V}_n - A\int_0^L k\,dx - B\int_0^L kx\,dx - \int_0^L kf(x)\,dx$$

$$(36)\quad 0 = \bar{M}_n - A\int_0^L\int_0^x k\,dx\,dx - B\int_0^L\int_0^x kx\,dx\,dx - \int_0^L\int_0^x kf(x)\,dx$$

Solving for A and B:

$$(37)\quad A = \frac{\left[\bar{V}_n - \int_0^L kf(x)\,dx\right]\left[\int_0^L\int_0^x kx\,dx\,dx\right] - \left[\int_0^L kx\,dx\right]\left[\bar{M}_n^* - \int_0^L\int_0^x kf(x)\,dx\,dx\right]}{\left[\int_0^L k\,dx\right]\left[\int_0^L\int_0^x kx\,dx\,dx\right] - \left[\int_0^L kx\,dx\right]\left[\int_0^L\int_0^x k\,dx\,dx\right]}$$

$$(38)\quad B = \frac{\left[\int_0^L k\,dx\right]\left[\bar{M}_n^* - \int_0^L\int_0^x kf(x)\,dx\,dx\right] - \left[\bar{V}_n - \int_0^L kf(x)\,dx\right]\left[\int_0^L\int_0^x k\,dx\,dx\right]}{\left[\int_0^L k\,dx\right]\left[\int_0^L\int_0^x kx\,dx\,dx\right] - \left[\int_0^L kx\,dx\right]\left[\int_0^L\int_0^x k\,dx\,dx\right]}$$

Substituting these values into (34) gives M^*.

$$(31)\quad \frac{d^2s}{dx^2} = \frac{M^*}{D}$$

Let:

$$(39)\quad g(x) = \int_0^x \frac{d^2s}{dx^2}\,dx = \int_0^x \frac{M^*}{D}\,dx$$

$$(40)\quad f_1(x) = \int_0^x g(x)\,dx$$

It will be noted that $g(x) \neq \frac{ds}{dx}$ and $f_1(x) \neq s$ because the initial conditions have not been included. We normalize $f_1(x)$ to obtain

$$(41)\quad f_2(x) = f_1(x) - \frac{f_1(L)x}{L}$$

and it may be seen that $f_2(0) = f_2(L) = 0$.

If $f_2(x)$ is used for $f(x)$ directly in equation (32) to perform the next iteration, the process usually diverges rapidly. To force convergence, the following averaging

procedure is used.

1. Let numbers m and C_{min}, chosen as described later, be specified.

2. Let d be the value of x for which $f_2(x)$ is maximal.

3. Determine a number C according to the rule:

   If $f(d) = 0$, $C = C_{min}$;

   If $|f(d)/f_2(d)| \geq 1$, $C = C_{min}$;

   If $0 < |f(d)/f_2(d)| < 1$, C equals the larger of C_{min} or $|f(d)/f_2(d)|^m$.

4. Obtain a new function $f_3(x)$ by the formula:

(42) $f_3(x) = Cf_2(x) + (1-C)f(x)$.

$f_3(x)$ is the function to be substituted into the equation (32) for f(x) in the next iteration. The process has converged when $f_2(x) \approx f(x)$.

The fraction $\left|\frac{f(d)}{f_2(d)}\right|^m$ is used solely to reduce the number of iterations required for convergence. It may be seen that when convergence has almost been attained, the fraction C will become progressively larger resulting in a higher percentage of $f_2(x)$ being used in the next iteration.

The number m must be kept to a minimum and C_{min} kept to a maximum to reduce the number of iterations to a minimum. It was found by trial and error that a value of

8 or 9 for m and .06 to .08 for C_{min} generally insured convergence. One problem required an m of 15 for reasons unknown to the writer. Generally if divergence is experienced, increasing m and decreasing C_{min} seems to eliminate the divergence.

When convergence has been attained, M_x, s, and $\frac{ds}{dx}$ are calculated as follows:

(43) $M_x = M^* - \frac{D(1+\mu)\alpha\Delta T}{t}$

(44) $\frac{ds}{dx} = B + g(x) - \frac{f_1(L)}{L}$

(45) $s = A + Bx + f_2(x)$

Using the sign conventions established in Figure 3 and with the understanding that "loadings" stand for the pressure, thermal loadings, and axial loading in each cylinder, let;

$\delta_{o1}, \delta_{o2}, \delta_{o3}$ = junction end deflections of the disconnected Cylinders 1,2, and 3 respectively due to their loadings.

$\delta_1, \delta_2, \delta_3$ = junction end deflections of Cylinders 1,2, and 3 respectively caused by joining the cylinders at the junction. The total deflection of Cylinder 1 would then be $\delta_{o1} + \delta_1$.

$\phi_{o1}, \phi_{o2}, \phi_{o3}$ = junction end slopes (subscripts have the same meanings as those for δ).
ϕ_1, ϕ_2, ϕ_3

M_{o1}, M_{o2}, M_{o3} = junction end moments of Cylinders 1,2, and 3 respectively.

V_{o1}, V_{o2}, V_{o3} = junction end shear loadings of Cylinders 1,2, and 3 respectively.

V_{oo} and M_{oo} = externally applied shear and moment at junction.

$A_{v\phi}$ = slope at junction end of Cylinder 1 produced by application of unit shear to junction end.

$A_{v\delta}$ = deflection at junction end of Cylinder 1 produced by application of unit shear to junction end.

$A_{m\phi}$ = slope at junction end of Cylinder 1 produced by application of unit moment to junction end.

$A_{m\delta}$ = deflection at junction end of Cylinder 1 produced by application of unit moment to junction end.

B and C denote similar coefficients for Cylinders 2 and 3 respectively, with the same subscripts and definitions as for A.

Note that ϕ_{o1}, ϕ_{o2}, $A_{v\phi}$, $A_{m\phi}$, $B_{v\phi}$, $B_{m\phi}$, $C_{m\phi}$, and $C_{m\delta}$ are the negatives of the end conditions calculated by the above iterative process, or analytical process, due to the difference in sign conventions between Figures 3 and 4. Figure 5 shows Cylinders 1,2, and 3, situated as in Figure 4 but with sign conventions as in Figure 3, and as used in these equations.

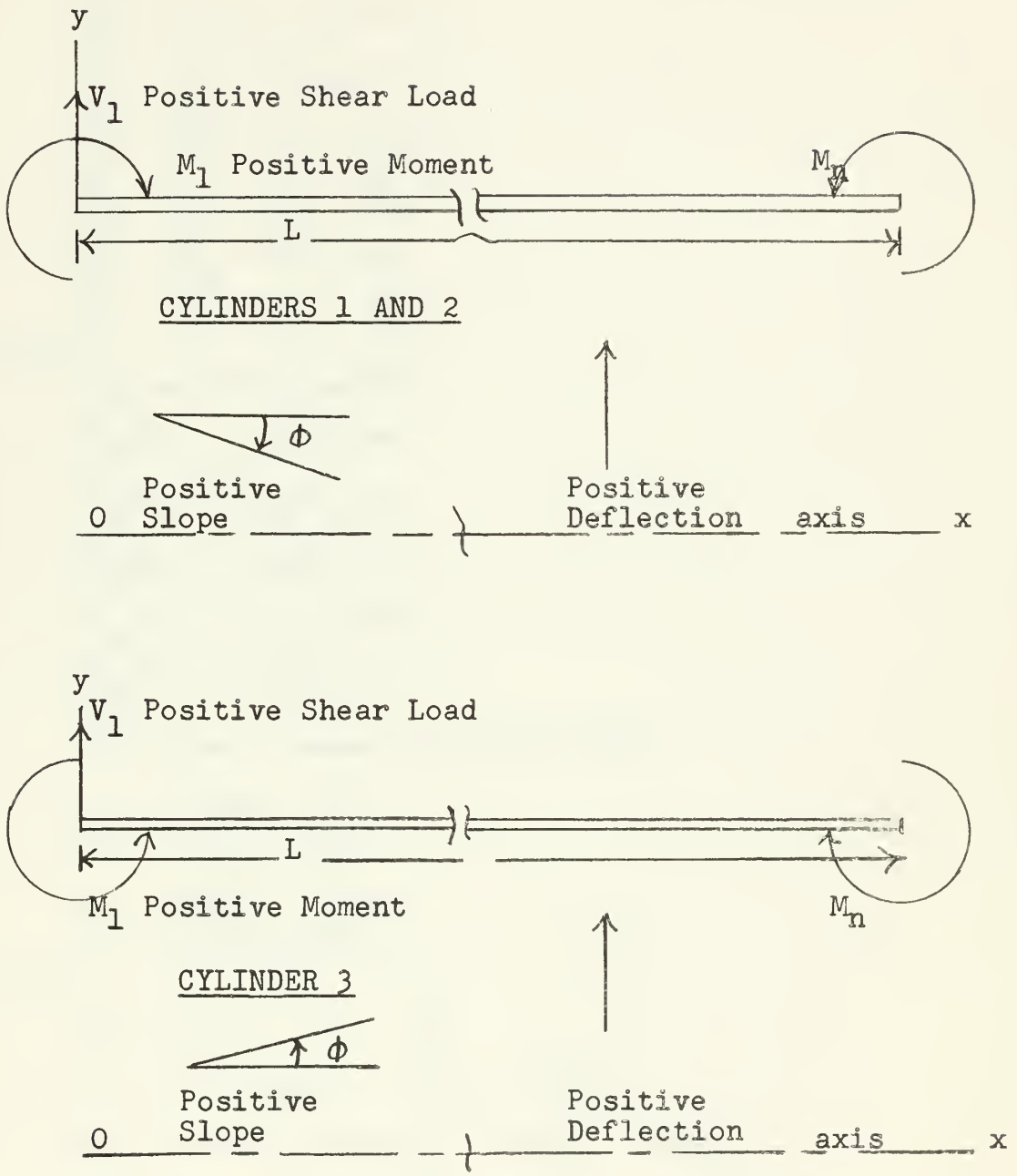


Figure 5. View of Cylinders 1,2, and 3, Showing Sign Conventions Used in Equations (46), (47), and (48).

From statics, compatibility, and other considerations:

$$
\begin{aligned}
&V_{o1} + V_{o2} + V_{o3} = V_{oo} \\
&M_{o1} + M_{o2} + M_{o3} = M_{oo} \\
&\delta_1 + \delta_{o1} = \delta_2 + \delta_{o2} \\
&\delta_1 + \delta_{o1} = \delta_3 + \delta_{o3} \\
&\phi_1 + \phi_{o1} = \phi_2 + \phi_{o2} \\
&\phi_1 + \phi_{o1} = \phi_3 + \phi_{o3} \\
&V_{o1}A_{v\phi} + M_{o1}A_{m\phi} = \phi_1 \\
&V_{o1}A_{v\delta} + M_{o1}A_{m\delta} = \delta_1 \\
&V_{o2}B_{v\phi} + M_{o2}B_{m\phi} = \delta_2 \\
&V_{o2}B_{v\delta} + M_{o2}B_{m\delta} = \delta_2 \\
&V_{o3}C_{v\phi} + M_{o3}C_{m\phi} = \phi_3 \\
&V_{o3}C_{v\delta} + M_{o3}C_{m\delta} = \delta_3
\end{aligned}
\tag{46}
$$

Solution of equations (46) yield:

$$
\begin{aligned}
M_{o2} &= \frac{P_2Q_1 - P_1Q_2}{N_1P_2 - P_1N_2} \\
M_{o3} &= \frac{N_1Q_2 - N_2Q_1}{N_1P_2 - N_2P_1} \\
M_{o1} &= M_{oo} - M_{o2} - M_{o3} \\
V_{o3} &= (1/I_1)(L_1 - J_1M_{o2} - K_1M_{o3}) \\
V_{o2} &= (1/D_1)(H_1 - E_1V_{o3} - F_1M_{o2} - G_1M_{o3}) \\
V_{o1} &= V_{oo} - V_{o2} - V_{o3}
\end{aligned}
\tag{47}
$$

where,

(48)
$$
\begin{aligned}
D_1 &= A_{v\phi} + B_{v\phi} \\
D_2 &= A_{v\phi} \\
D_3 &= A_{v\delta} + B_{v\delta} \\
D_4 &= A_{v\delta} \\
E_1 &= A_{v\phi} \\
E_2 &= A_{v\phi} + C_{v\phi} \\
E_3 &= A_{v\delta} \\
E_4 &= A_{v\delta} + C_{v\delta} \\
F_1 &= A_{m\phi} + B_{m\phi} \\
F_2 &= A_{m\phi} \\
F_3 &= A_{m\delta} + B_{m\delta} \\
F_4 &= A_{m\delta} \\
G_1 &= A_{m\phi} \\
G_2 &= A_{m\phi} + C_{m\phi} \\
G_3 &= A_{m\delta} \\
G_4 &= A_{m\delta} + C_{m\delta} \\
H_1 &= \phi_{o1} - \phi_{o2} + V_{oo} A_{v\phi} + M_{oo} A_{m\phi} \\
H_2 &= \phi_{o1} - \phi_{o3} + V_{oo} A_{v\phi} + M_{oo} A_{m\phi} \\
H_3 &= \delta_{o1} - \delta_{o2} + V_{oo} A_{v\delta} + M_{oo} A_{m\delta} \\
H_4 &= \delta_{o1} - \delta_{o3} + V_{oo} A_{v\delta} + M_{oo} A_{m\delta} \\
I_1 &= D_2 E_1 - D_1 E_2 \\
I_2 &= D_3 E_2 - D_2 E_3 \\
I_3 &= D_4 E_3 - D_3 E_4
\end{aligned}
$$

$$
(48)\quad
\begin{vmatrix}
J_1 = D_2F_1 - D_1F_2 \\
J_2 = D_3F_2 - D_2F_3 \\
J_3 = D_4F_3 - D_3F_4 \\
K_1 = D_2G_1 - D_1G_2 \\
K_2 = D_3G_2 - D_2G_3 \\
K_3 = D_4G_3 - D_3G_4 \\
L_1 = D_2H_1 - D_1H_2 \\
L_2 = D_3H_2 - D_2H_3 \\
L_3 = D_4H_3 - D_3H_4 \\
N_1 = I_2J_1 - I_1J_2 \\
N_2 = I_3J_2 - I_2J_3 \\
P_1 = I_2K_1 - I_1K_2 \\
P_2 = I_3K_2 - I_2K_3 \\
Q_1 = I_2L_1 - I_1L_2 \\
Q_2 = I_3L_2 - I_2L_3
\end{vmatrix}
$$

Let M_{1x}, M_{2x} and M_{3x} represent the axial moments in Cylinders 1,2, and 3 respectively. M_{L1}, M_{L2}, and M_{L3} represent the axial moments in Cylinders 1,2, and 3 caused by the thermal, pressure and axial loadings. M_{v1}, M_{v2}, and M_{v3} represent the axial moments in Cylinders 1,2, and 3 respectively caused by application of a unit shear load to their junction ends. M_{m1}, M_{m2}, and M_{m3} represent the axial moments in Cylinders 1,2, and 3 respectively caused by application of a unit moment to their junction ends.

The subscripts for V and s have comparable meanings.

Then:

$$
(49)\quad
\begin{cases}
M_{1x} = M_{L1} + V_{o1}M_{v1} + M_{o1}M_{m1} \\
M_{2x} = M_{L2} + V_{o2}M_{v2} + M_{o2}M_{m2} \\
M_{3x} = M_{L3} + V_{o3}M_{v3} - M_{o3}M_{m3} \\
V_{1x} = V_{L1} + V_{o1}V_{v1} + M_{o1}V_{m1} \\
V_{2x} = V_{L2} + V_{o2}V_{v2} + M_{o2}V_{m2} \\
V_{3x} = V_{L3} + V_{o3}V_{v3} - M_{o3}V_{m3} \\
s_{1x} = s_{L1} + V_{o1}s_{v1} + M_{o1}s_{m1} \\
s_{2x} = s_{L2} + V_{o2}s_{v2} + M_{o2}s_{m2} \\
s_{3x} = s_{L3} + V_{o3}s_{v3} - M_{o3}s_{m3}
\end{cases}
$$

Substituting the results of (49) into (25), (26), (27), and (28) gives the desired stresses along the cylinders.

In the above development it was assumed that the head and shell (Cylinders 2 and 3) were in fact cylinders and that their pressure stresses could be computed accordingly. Call this method Option 1. If one or both are not cylinders but some other shell of revolution (ellipsoid, cone, etc.), an error will result in the stress computations by considering them cylinders. (See problems 10 and 20, Appendix C.) One way to reduce this error is to use the above methods to obtain the reactions resulting from all loadings but pressure, and then superpose the separately calculated reactions due to pressure. Call this method Option 2.

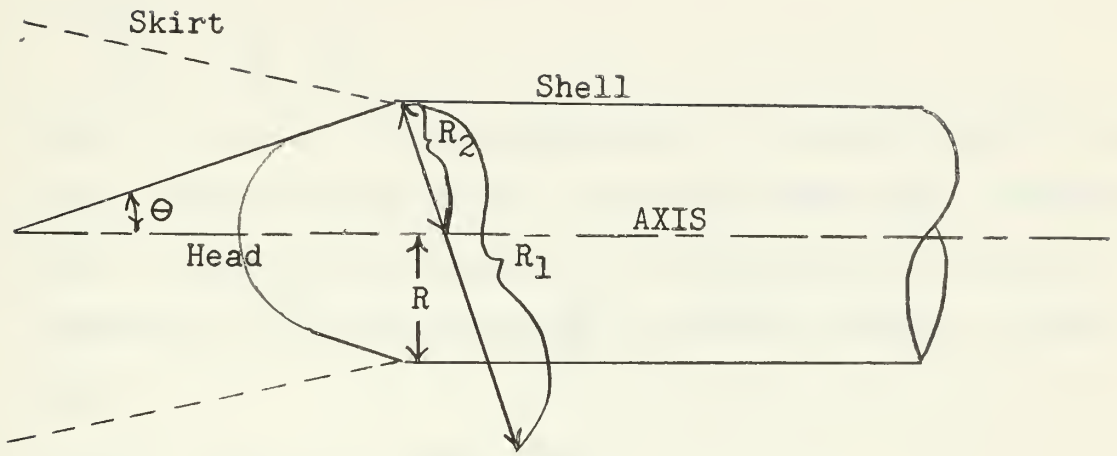


Figure 6. Shell Head, and Skirt Showing R1 and R2.

Consider the shell and head shown in Figure 6. In this particular case the head is Cylinder 2 and the vessel shell is Cylinder 3 but the following development will allow a noncylindrical element for either the shell, head, or both. The vessel shell is a cylinder, the head is some other shell of revolution. R is the radius of the vessel at the junction, R_1 is the radius of curvature of the meridian of the head at the junction, and R_2 is the radius of curvature of the line in the head perpendicular to the meridian at the junction. From Figure 6, $\frac{R}{R_2} = \text{Cos}\,\Theta$, where Θ is formed by the axis and the tangent to the meridian at the junction.

From membrane theory: [3]

$$(50)\quad \frac{\sigma_1}{R_1} + \frac{\sigma_2}{R_2} = \frac{p}{t}$$

where σ_1 and σ_2 are the meridional and circumferential (or hoop) stresses respectively, p is the inner gage pressure, and t is the wall thickness. At the junction the axial component of σ_1 must equal $\frac{pR}{2t}$ to satisfy statics. Therefore:

$$(51)\quad \sigma_1 = \frac{pR}{2t\mathrm{Cos}\theta} = \frac{pRR_2}{2tR} = \frac{pR_2}{2t} \quad .$$

From (50):

$$(51a)\quad \sigma_2 = R_2\left[\frac{p}{t} - \frac{\sigma_1}{R_1}\right] = R_2\left[\frac{p}{t} - \frac{pR_2}{2tR_1}\right]$$

Let δ_o' be the radial deflection due to pressure.

$$\delta_o' = \left[\frac{R_2}{E}\,\frac{R}{R_2}\right]\left[\sigma_2 - \mu\sigma_1\right]$$

$$(52)\quad \delta_o' = \left[\frac{R}{E}\,R_2\right]\left[\frac{p}{t} - \frac{p}{2tR} - \frac{\mu p}{2t}\right]$$

There is also an inward radial force at the junction, V_{oo}' due to the component of σ_1 perpendicular to the axis.

$$(53)\quad V_{oo}' = -\sigma_1 t\mathrm{Sin}\theta = \frac{-p\sqrt{R_2^2 - R_1^2}}{2}$$

The suggested procedure for computing the effects of pressure in Option 2 is first to calculate the inputs to

equations (48) setting internal pressure equal to zero but considering all other loadings and external loadings. δ'_{o2} and δ'_{o3} are then calculated and added to δ_{o2} and δ_{o3}. V'_{oo} is calculated as the sum of the contributions of both Cylinders 2 and 3 and is added to V_{oo}. Using equations (47), (49), (25), and (26), the longitudinal and circumferential stresses are computed. However, it will be noted that these stresses contain only those pressure stresses caused by the dissimilar deflections and consequent bending of Cylinders 2 and 3. The direct membrane pressure stresses must still be added as follows:

$$(54)\quad \begin{cases} \sigma_{x\ \text{outer}} = \sigma_{x\ \text{outer}}\ (\text{from (25)}) + \sigma_1 \\ \sigma_{x\ \text{inner}} = \sigma_{x\ \text{inner}}\ (\text{from (25)}) + \sigma_1 \\ \sigma_{z\ \text{outer}} = \sigma_{z\ \text{outer}}\ (\text{from (26)}) + \sigma_2 \\ \sigma_{z\ \text{inner}} = \sigma_{z\ \text{inner}}\ (\text{from (26)}) + \sigma_2 \end{cases}$$

These values may then be substituted into (27) and (28) to obtain the equivalent stresses.

Note that with Option 1 the effects of internal pressure are calculated in the numerical solution of the differential equations and therefore any variations in the parameters of either cylinder will be taken into account. These variations will cause moments and shears in the cylinder itself before consideration is given to its junction

with the others. With Option 2, the only moments and shears due to pressure that are calculated are those caused by the dissimilar deflections at the junction end of each cylinder. Either option treats all three shells as cylinders when calculating the effects of other than pressure loadings. For this reason either option will err in treating axial force in a shell with other than zero meridianal curvature since, among other things, the cylindrical equations do not consider the radial component of σ_x.

4. Digital Computer Program

At first the goal of this thesis was to develop a method in which a complicated hot skirt problem could be solved on a desk calculator in no more than a day. This goal was not met due to the number of iterations necessary for convergence.

To make the method more useful, a digital computer program which closely parallels the method outlined in the previous section was written in the CDC 1604 Fortran 60 language. There are some small deviations in sequence of operations mainly due to the fact that the program progressively grew as it became more apparent that a manual solution was becoming impractical for any problem in which the parameters of the cylinders varied axially. A standard library program is used to solve equations (46).

The program also provides for longitudinal slots in a portion of a cylinder (usually the skirt). Cheng and Weil [2] have indicated that slotting the skirt at the junction substantially reduces the stresses in the cylinders.

The slots are considered narrow enough so that the loss of metal in them may be neglected. The slotted section is considered to be a series of separate cantilever plates with no interaction between adjacent plates and, consequently, no σ_{mz} along their slotted lengths, where σ_{mz} is

the stress at the midplane in the z direction. There is of course some σ_{mz} at the junction end of a slotted skirt due to the strain of the junction itself and therefore this is not an exact representation of the actual situation. However provision is made in the program to start and end the slot at any distance from the junction one might choose, and a way might be found to simulate the junction conditions by starting the slot at some predictable distance from the junction. This slotted shell capability was provided mainly so that others may have a useful tool for systematically investigating the effects of such slots.

The following alterations are made to the equations in the program at those stations where the cylinder is slotted:

1. Q of equation (32) is set equal to zero since all terms except p are functions of interactions between adjacent longitudinal segments of the cylinder. If the cylinder were slotted it could carry no internal pressure.
2. For the same reasons all the terms except the $6Mx\mu/t^2$ term are set equal to zero in equations (26).

The program uses a midordinate integration scheme which, as programmed, wastes about half as much memory space

in the computor as it employs. It was originally used because it is systematic and very convenient for hand calculations. If limitations should thereby be imposed upon the utility of the program, more compact integrating methods could be used.

The program was written so that only the minimum number of input cards necessary to describe the problem is required. For example if only the first and last stations of a cylinder are described, the program uses the cylinder parameters of the first station for the remaining intermediate stations and makes a linear interpolation of the thermal and axial load inputs. The internal pressure is assumed constant. See Appendix A for a detailed explanation.

Three output options are available to the user:

1. Only the maximum equivalent stress (based on the distortion energy theory) and its location is given for each cylinder.
2. The inner and outer longitudinal, circumferential, and equivalent stresses are given for each station of each cylinder.
3. The inner and outer longitudinal and circumferential stresses and the moment and shear are given for each station of each cylinder.

With each option all of the input data is repeated, and a short explanation of the output is printed.

The program takes about one minute to compile and each problem requires from one half minute to one minute. It took about seven minutes to compile and solve the eleven problems in Appendix C. The program uses only the normal Fortran functions and language as described by McCracken [4] and therefore should be easily adaptable to any large digital computer having a Fortran system.

5. Conclusion

Even though the method was developed specifically to solve the "Hot Skirt" problem, the reader is reminded that with suitable manipulations of the input, many other problems may be solved.

The only restrictions are the following:

1. Elastic behavior.
2. Axial symmetry.
3. Maximum of three shells arranged as in Figure 3.
4. Constant internal pressure in Cylinders 2 and 3 only.
5. "Thin" wall.
6. Linear temperature variation in radial direction.
7. Configurations of shells such that their reactions to an end load may be approximated by regarding them as cylinders of the same radius, wall thickness, and material. (Thus, treating a very shallow elliptical head as such probably would result in appreciable error.)

Some useful extensions of the development would be:

1. A complete revision of the theory so as to include a radius of curvature in the xz plane. This would eliminate the restrictions imposed by the use of the cylindrical equations.
2. An alteration to allow inelastic behavior. This

would probably take the form of a series of repetive stress calculations, increasing the loading until yielding begins, and then a different set of calculations until the full loading is applied.

3. A modification to accommodate "thick" shells such as are found in reactor pressure vessels.
4. A modification to allow radially variable material parameters such as would be found in a reactor pressure vessel with internal cladding.
5. Modification to include the moments due to axial forces acting through offsets in radii or through radial deflections.

BIBLIOGRAPHY

Numbers 1 through 5 cited in text or Appendices

1. Weil, N.A. and Murphy, J.J., "Design and Analysis of Welded Pressure-Vessel Skirt Supports," Journal of Engineering for Industry, Vol. 82, No. 1, February 1960.

2. Cheng, D.H. and Weil, N.A., "The Junction Problem of Solid-Slotted Cylindrical Shells," Journal of Applied Mechanics, Vol. 27, No. 2, June 1960.

3. Timoshenko, S., Strength of Materials, Parts I and II, D. Van Nostrand Company, Inc., Princeton, New Jersey, March 1956.

4. McCracken, D.D., A Guide to Fortran Programming, John Wiley & Sons, Inc., New York, N.Y., 1961.

5. Bergman, D.J., "Temperature Gradients in Skirt Supports of Hot Vessels," ASME - Paper 62-PET-41 for meeting September 23-26, 1962.

6. Bijlaard, P.P., and Dohrmann, R.J., "Thermal-Stress Analysis of Irregular Shapes," Journal of Engineering for Industry, Vol. 83, No. 4, November 1961.

7. Weil, N.A., and Rapasky, F.S., "Experience with Vessels of Delayed-Coking Units," Proceedings of API, Division of Refining, Vol. 38, No. III, 1958.

APPENDIX A

Instructions for use of Program Skirt

These pages are intended to serve both as Appendix A of the thesis

"Thermal Stress Analysis of Pressure Vessels with Cylindrical Skirt Supports"

by James P. McManus, May 1964,

and as an independent document describing the employment of Program Skirt to solve certain stress-analytical problems for pressure vessels. The theory upon which Program Skirt is based is developed in detail in the above mentioned thesis. Those interested in studying the larger document should make inquiry from Head Librarian: U. S. Naval Postgraduate School, Monterey, California.

Given three axisymmetric shells joined together and numbered as shown in Figure (A1). These shells may be subjected to the following axisymmetric loads:

1. Changes in temperature proceeding axially along any or all of the shells.
2. Changes in temperature (assumed to vary linearily) through the thickness of a shell.
3. Internal pressure in Shells 2 and 3 but not in Shell 1.
4. An additional axial loading on any or all of the

shells. (Could be the dead weight of one of the shells and its contents.)

5. A moment applied to the junction of the three shells by agencies external to the shells.
6. A radially outward distributed loading applied to the junction by agencies external to the shells.

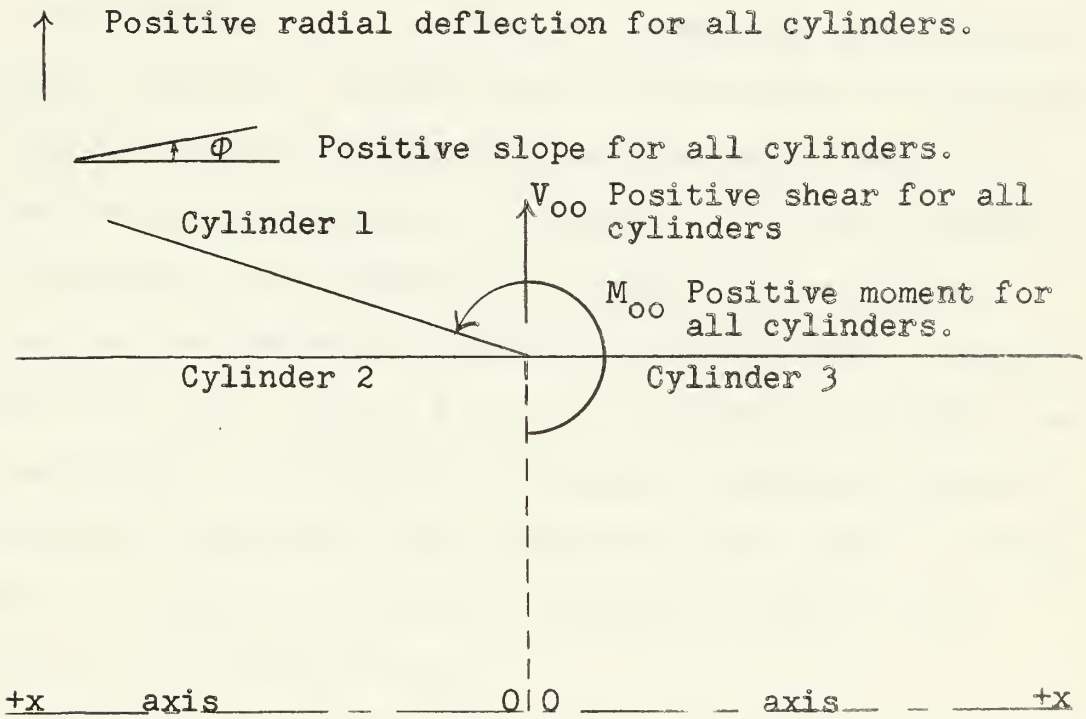


Figure A1. Positions of Three Cylinders and Sign Conventions

Program Skirt solves the problem using simple numerical techniques. The user must choose a finite length for each shell such that loads applied at the remote end of the shell have no appreciable effect on the junction end, except that

axial loads are fully transmitted. Suggested values for the lengths are given in the remarks on Card 2. Each finite shell is then divided into n-1 equal increments with the dividing stations numbered from 1 at the junction to n at the remote end. Data for each station such as shell parameters and loadings is either read into the computer, or created by the computer from data given about adjacent stations.

Two options are available for computing the effects of internal pressure. Either option may be used if the shells are uniform and are cylindrical or have small meridional curvature near the junction. Option 1 is to be preferred if the shells are cylindrical or have small meridional curvature, but there are variations in thickness, material properties, etc. Option 2 is to be preferred if there are no variations of thickness or material properties but the meridional curvature at the junction is not small. Neither option is capable of obtaining accurate results if the shell is not relatively deep.

The following assumptions have been made in the program:

1. The three shells act as elastic cylinders. The shells may have "slowly variable" radii, thickness, and material properties, but are still treated as cylinders from station to station.

2. Temperature varies linearly through the wall thickness.

3. Shear and curvature are negligible at the remote end. If there are nonlinearities near the remote end such as variation in the shell parameters, nonlinear axial thermal gradient, or a changing radial gradient or axial load, the values of stress obtained near the remote end will be inaccurate.

Description of Input Cards

The input consists of all the parameters necessary to describe the problem plus some control parameters to direct the method of solution and the format of the output. In the descriptions below the items given from left to right are: Column Numbers, Format, Parameter, Remarks. When a parameter has an "I" Format Field, its last digit must be in the last column of its field.

Card Type I (One card only)

1-10	I10	Problem number	May be 1 through 999. If it is zero or blank, the program stops.
11-20	I10	Output option number	1, 2, or 3 1 Only maximum equivalent energy stresses* and loca-

*Equivalent on basis of distortion energy theory.

			tion given for each cylinder. 2 Longitudinal, circumferential and equivalent stresses given for each station of each cylinder. 3 Longitudinal and circumferential stresses, and moment and shear given for each station of each cylinder.
21-30	F10.0	Externally applied moment to junction	Positive if causing compression on outer surface of Cylinders 1 and 2. (Moment per unit circumference.)
31-40	F10.0	Externally applied shear to junction	Positive if directed radially outward. (Shear load per unit circumference.)
41-50	F10.0	Pressure	Gage pressure in Cylinders 2 and 3.
51-60	I10	Code for handling pressure	If 1, Option 1 is used. (See above.) If 2, Option 2 is used.

61-70	F10.0	Minimum fraction	The minimum value of a fraction C_{min} used in the averaging routine for assisting convergence. Recommend from .06 to .08. If left blank, .06 substituted. Values less than .06 might be necessary if divergence is experienced.
		Card Type 2	(Three cards required)
1- 5	I5	Cylinder number	1, 2, or 3. Must be in sequence.
6-10	I5	Number of increments	Maximum of 100.
11-15	I5	Interval of printout for input data	Example: If 2, every other station reported; if 5, every fifth station reported, etc.
16-20	I5	Exponent for forcing convergence	Suggest 8 to 12. If divergence is experienced, use a higher value. The higher the exponent, the greater the computer time required. 11 substituted if left blank.

21-30	F10.0	Minimum x	See below.* x at junction end.
31-40	F10.0	Maximum x	See below.* x at remote end.
41-50	F10.0	Convergence criterion	Suggested values from .01 to .05. This is an approximate indication of the relative error in the results. Smaller values require longer computer time.
51-60	F10.0	Value of x at beginning of slots	For use with longitudinally slotted sylinders.
61-70	F10.0	Value of x at end of slots	For use with longitudinally slotted cylinders.

Card Type 3 (Two or more cards for each cylinder)

1- 5	I5	Station number	1 through n, where n is the number of increments plus one.

*The program allows x, the axial dimension in inches, to be other than zero at the junction if the user so desires. It is recommended that the length of the cylinder be approximately six times the square root of the radius times the wall thickness, or $6\sqrt{at}$.

6-20	F15.0	Young's Modulus at this station
21-35	F15.0	Mean radius of cylinder at this station
36-50	F15.0	Poisson's ratio at this station
51-65	F15.0	Wall thickness at this station
66-80	F15.0	Thermal coefficient of expansion at this station

Note: There must be Cards 3 for the first and last stations. The first station is number 1 and the last is n. If there is no card for an intermediate station, the values for the previous station are substituted. Therefore to change a value, simply feed in a card for the appropriate station. The cards submitted must be in numerical sequence by station number. The minimum number of Cards 3 for a cylinder is two, the maximum number is n.

Card Type 4 (Two or more cards for each cylinder)

1-10	I10	Station number

11-20	F10.0	Mean temperature at this station	
21-30	F10.0	Radial temperature difference	Temperature at inside wall minus temperature at outside wall.
31-40	F10.0	Axial load	Total axial load imposed upon cylinder due to all causes except pressure. Positive if causing tension. Note that this is not load per unit circumference, but total load.

Note: There must be Cards 4 for the first and last stations. If no card is submitted for a series of stations, a linear interpolation of the temperatures and load is made between stations that have cards. The cards must be in sequence. Same minimum and maximum number of cards as with Card 3.

Card Type 5 (No cards or two cards)
(Used only when Option 2 is used for pressure stresses.)

1-10	F10.0	Radius of meridian at junction. (R_1 in Figure A2) Infinity substituted if blank.
11-20	F10.0	Radius of circumference at junction divided by the cosine of the angle between the tangent to

the meridian and the axis. (R_2 in Figure A2.)
Radius of junction substituted if blank.

Note: There must be Cards 5 after the last Card 4 for Cylinders 2 and 3 whenever the pressure Option 2 is used.

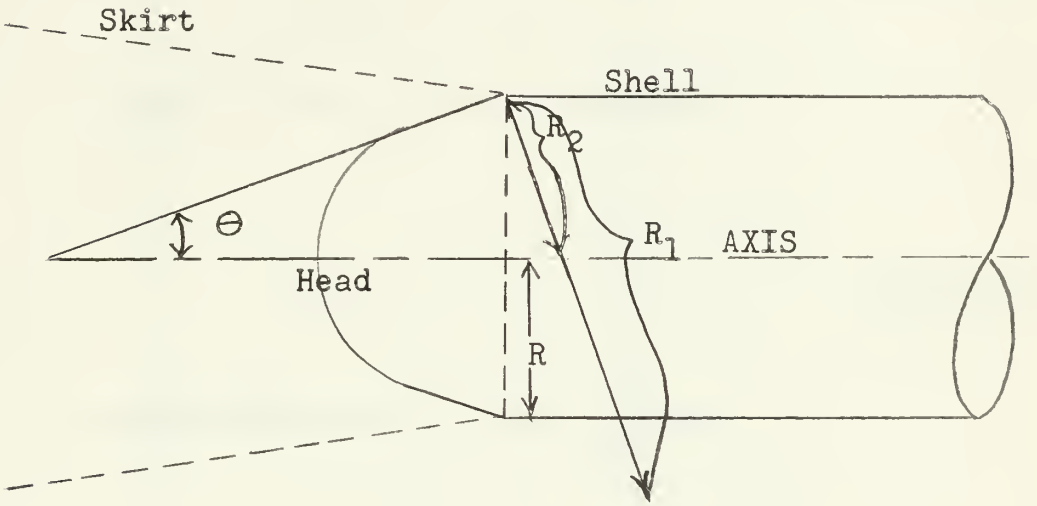


Figure A2. Shell, Head, and Skirt. Showing R_1 and R_2.

Following is an example of the sequence of data cards for the input of one problem to the program.

Pressure stress calculated by Option 1	Pressure stress calculated by Option 2	
Card 1	Card 1	
2	2	
3	3	
-	-	
-	-	
3	3	
4	4	Cylinder 1
-	-	
-	-	
4	4	
2	2	
3	3	
-	-	
-	-	
3	3	
4	4	Cylinder 2
-	-	
-	-	
4	4	
no card	5	
2	2	
3	3	
-	-	
-	-	
3	3	
4	4	Cylinder 3
-	-	
-	-	
4	4	
no card	5	

-Denotes the series of Cards 3 and 4 necessary to describe the problem.

If the problem involves fewer than three cylinders, the effects of the cylinders not to be considered may be eliminated by setting their length equal to a very small number. The program will still give results for these shortened cylinders but they might be inaccurate due to round off

error and should be ignored.

The minimum fraction (columns 61-70, Card 1) and exponent for forcing convergence (columns 16-20, Card 2) are values used in an averaging process to assist in obtaining convergence of the numerical solution of the fourth order differential equation of a cylinder. These values are named C_{min} and m respectively in the main body of the thesis.

The convergence criterion (columns 41-50, Card 2) is multiplied by the maximum radial deflection of the cylinder and this value is compared with the change in radial deflection at each station for the last two successive iterations. If this change for every station is less than the maximum deflection times the convergence criterion, convergence is deemed to have been attained.

The program is stopped by placing a blank card in place of Card 1.

APPENDIX B

Listing of Program Skirt and Logical Flow Chart

List of Variables in Main Body of Program

Name in Program	Counterpart in Thesis	Description
A	Numerous	Inputs to continuity and statics equations. (Equations (46) in thesis, reduced to 6X6 array.)
AA	-	Instruction code for integration subroutine "Zigzag".
AAA	-	0 if no divergence experienced in problem; 1 if divergence experienced.
AINC	-	Number of increments.
AL	α	Coefficient of linear thermal expansion.
AMBAR	$\bar{M}^* - \int_0^x \bar{V} dx$	Junction end moment plus the moment necessary to compensate for that imposed by the radial thermal gradient.
AMO	M_1	Moment at junction end.
AMOO	M_{oo}	Externally applied moment to junction.
AV	A	Deflection at junction end.
AX	V_{o1}, V_{o2}, V_{o3}, M_{o1}, M_{o2}, M_{o3}	The end shear and moment for each cylinder.
B	Numerous	Inputs to continuity and statics equations. (Equations (46) in thesis, reduced to 6X6 array.)

BM	M, M^*	Moment in cylinder wall per unit circumference.
BM1	M_L	Moment in cylinder wall caused by thermal, pressure, and axial loadings.
BM2	M_v	Moment in cylinder wall caused by applying a unit shear to the junction end.
BM3	M_m	Moment in cylinder wall caused by applying a unit moment to the junction end.
BV	B	Slope of a straight line drawn between radial deflections plotted for junction and remote ends.
CURVE	χ_x	Axial curvature of cylinder wall.
CX	(k)(x)	CX = (C)(X)
CX1	-	$\int_0^X CXdX$
CX2	-	$\int_0^X CX1dX$
C	k	Pressure necessary to increase the radius of the cylinder one inch.
C1	-	$\int_0^X CdX$
C2	-	$\int_0^X C1dX$
E	E	Young's Modulus.
EI	D	Axial stiffness of a unit width segment of the cylinder wall.
ERROR	-	Convergence criterion fraction.
FM	C_{min}	Minimum fraction in convergence assistance routine.

FRAC	C	Fraction used in convergence assistance routine.
FX	f(x)	Deviation of radial deflection from a linear function.
FXC	(k)f(x)	FXC = (FX)(C)
FXC1	-	$\int_0^X FXC\,dX$
FXC2	-	$\int_0^X FXC1\,dX$
F1X	$f_1(x)$	$\int_0^X GX\,dX$
F2X	$f_2(x)$	Normalized F1X.
GX	g(x)	$\int_0^X (BM/D)\,dx$
H	t	Thickness of cylinder wall.
ICYL	-	Cylinder number.
IEXP	m	Exponent in convergence assistance routine.
IIF	-	Printout option.
INC	n-1	Number of equal increments into which the cylinder is divided.
INC2	-	(2)(INC) + 1
IND	-	Interval of printout of input data.
IPROB	-	Problem number.
IWILL	Option 1 or 2	Pressure stress calculation option.
JJ	-	Code for type of calculation presently in progress.
K1	-	First station in a sequence in which the loadings were not read into the computer.

K2	-	First station in a sequence in which the loadings were read into the computer.
K3	-	(K2 - K1 + 2)/2
L	-	Station number where maximum F2X occurs.
LL	-	Station number where maximum deflection occurs.
NAA	-	Number of Iterations.
PSI	p	Internal pressure.
PSI1	p	Internal pressure.
R	a	Radius of cylinder.
R1	R_1	Meridional radius of curvature of at junction.
R2	R_2	Radius of curvature of line perpendicular to meridian at junction.
SIG1	σ_1	Longitudinal membrane stress due to pressure.
SIG2	σ_2	Circumferential membrane stress due to pressure.
SL	$\frac{ds}{dx}$	Axial slope of cylinder wall.
SLOT	-	Value of X at end of slots.
SLOT1	-	Value of X at beginning of slots.
ST	$\frac{\alpha E \Delta T}{2}$	Stress at surface of wall of an infinite cylinder subjected to a radial temperature gradient.
STCI	$\sigma_{z \text{ inner}}$	Circumferential stress on inner wall surface.

STCO	$\sigma_{z \text{ outer}}$	Circumferential stress on on outer wall surface.
STLI	$\sigma_{x \text{ inner}}$	Longitudinal stress on inner wall surface.
STLO	$\sigma_{x \text{ outer}}$	Longitudinal stress on outer wall surface.
TL	T	Mean temperature.
TLINC	-	Increment of linear interpolation for TL.
TP	-	Number of 53 word blocks needed to store one parameter of cylinder.
TPI	-	Total number of 53 word blocks necessary to store on tape the intermediate values of one problem.
TR	ΔT	Difference between inner and outer wall temperature.
TRINC	-	Increment of linear interpolation for TR.
UM	μ	Poisson's ratio.
V	V	Radially outward directed load per unit circumference.
VBAR	-	Constant shear imposed at junction end.
VBAR1	-	$\int_0^X VBARdX$
VO	V_1	Shear at junction end.
VOO	V_{oo}	Externally applied shear force to junction.
V1	V_L	Shear in cylinder wall caused by thermal, axial, and pressure loadings.

V2	V_v	Shear in cylinder wall caused by applying a unit shear to the junction end.
V3	V_m	Shear in cylinder wall caused by applying a unit moment to the junction end.
WT	$(P^*)(2\pi a)$	Total axial load caused by all influences other than pressure.
WTINC	-	Increment of linear interpolation for WT.
W	$Q+\frac{Et}{a^2}(A+Bx+f(x))$	Distributed axial loads applied to cylinder including simulated thermal loads.
W1	-	$\int_0^X W dX$
W2	-	$\int_0^X W1 dX$
X	x	Axial dimension.
XDEL	-	Length of interval between stations.
XMAX	x_n	Value of X at remote end.
XMIN	x_1	Value of X at junction.
Y	s	Radial deflection.
Y1	S_L	Radial deflection of the cylinder wall caused by thermal, pressure, and axial loadings.
Y2	s_v	Radial deflection of the cylinder wall caused by applying a unit shear to the junction end.

Y3	s_m	Radial deflection of the cylinder wall caused by applying a unit moment to the junction end.

The following variables are those used in Subroutine Zigzag.

Variable	Description
A	Instruction code for integration.
B	Interval length.
D	Integrand.
E	Integral.
M	(2)(number of increments) + 1.

The following variables are those used in Subroutine Answer.

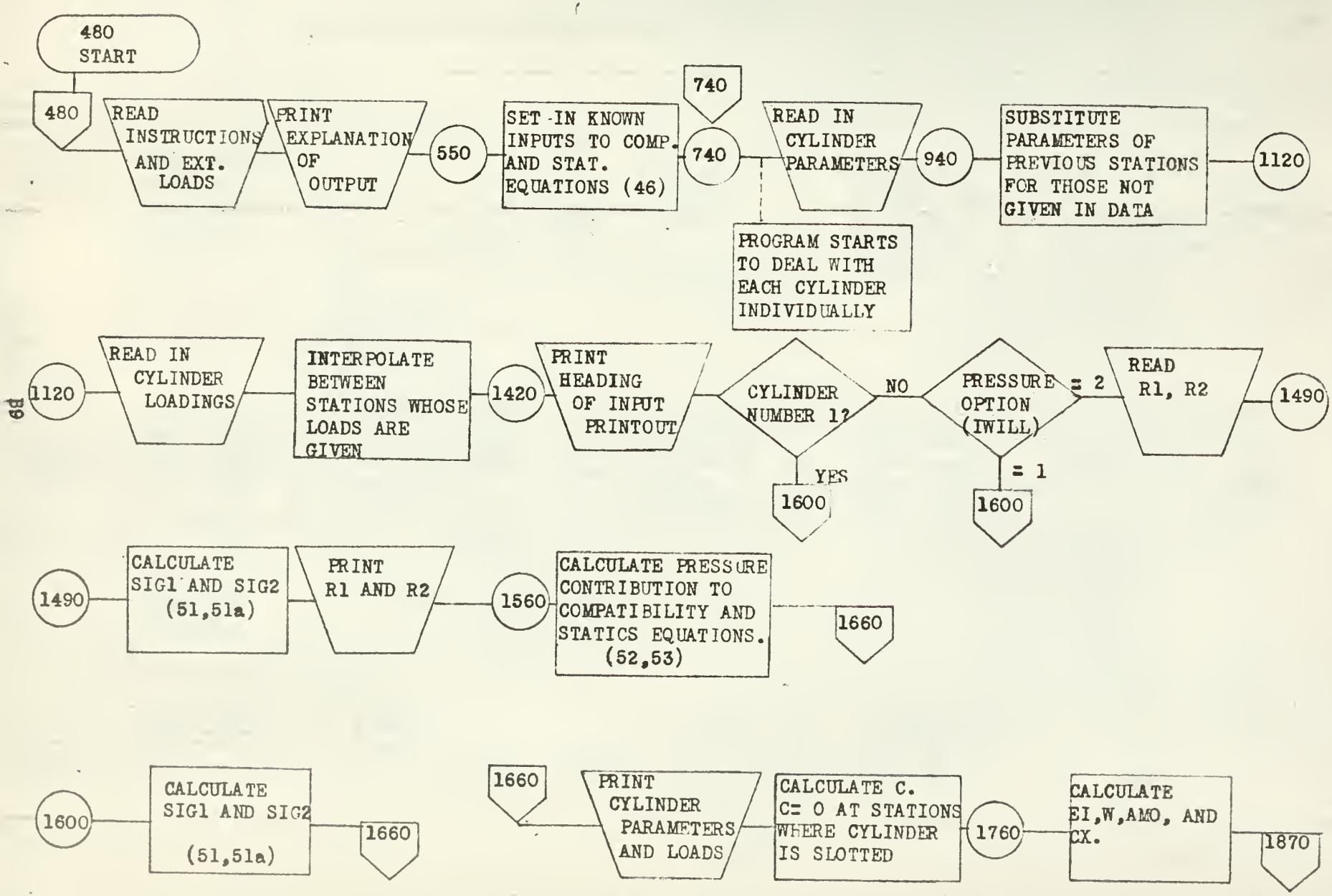
A	Equivalent stress on outer wall surface.
B	Equivalent stress on inner wall surface.
BM	Moment.
C	Outer longitudinal stress.
D	Inner longitudinal stress.
E	Outer circumferential stress.
F	Maximum equivalent stress.
G	Inner circumferential stress.
KK	Denotes whether maximum equivalent stress is on inner or outer surface of wall.
KKK	Station number of location of maximum equivalent stress.
L	Cylinder number.

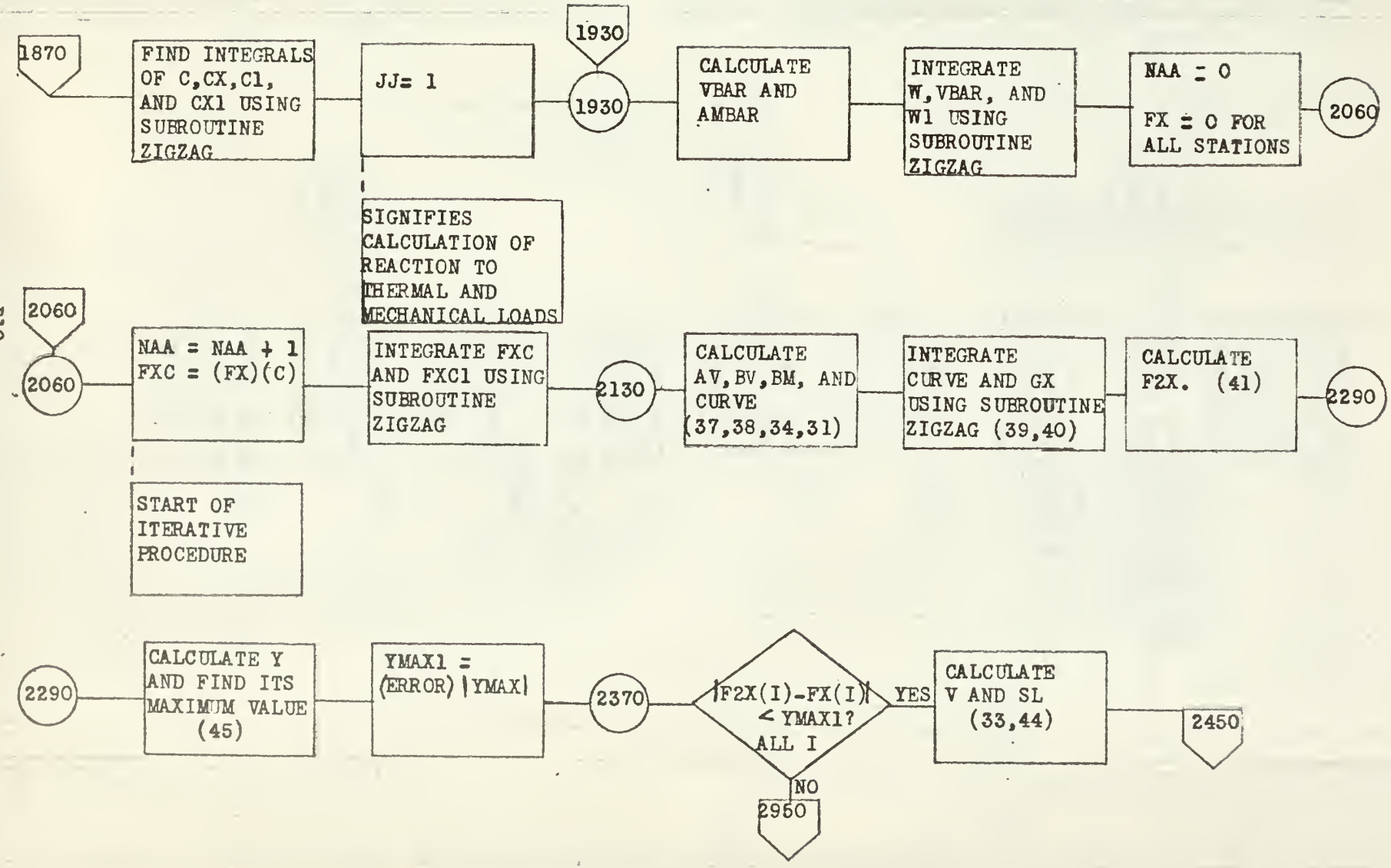
M	Number of increments.
N	Printout code.
NN	Problem number.
V	Shear.
X	Longitudinal dimension.

The symbols used in the following logical flow chart are from the "Flowcharting Template," Form X20-8020, of International Business Machines Corporation, and are described below. The numbers in the locator (circle) and connector (inverted house) correspond to the sequence numbers at the extreme right of the program listing.

Symbol		Use
Oval	Terminal	The beginning of end of a program.
Circle	Locator	The location of the first statement of the following operation in the program.
Trapezoid	Input/Output	Any function of an input/output device.
Inverted House	Connector	An entry from, or an exit to, another part of the program flowchart.
Diamond	Decision	A decision is made for routing to different branches of the program.
Rectangle	Processing	A group of instruction performing a processing function.

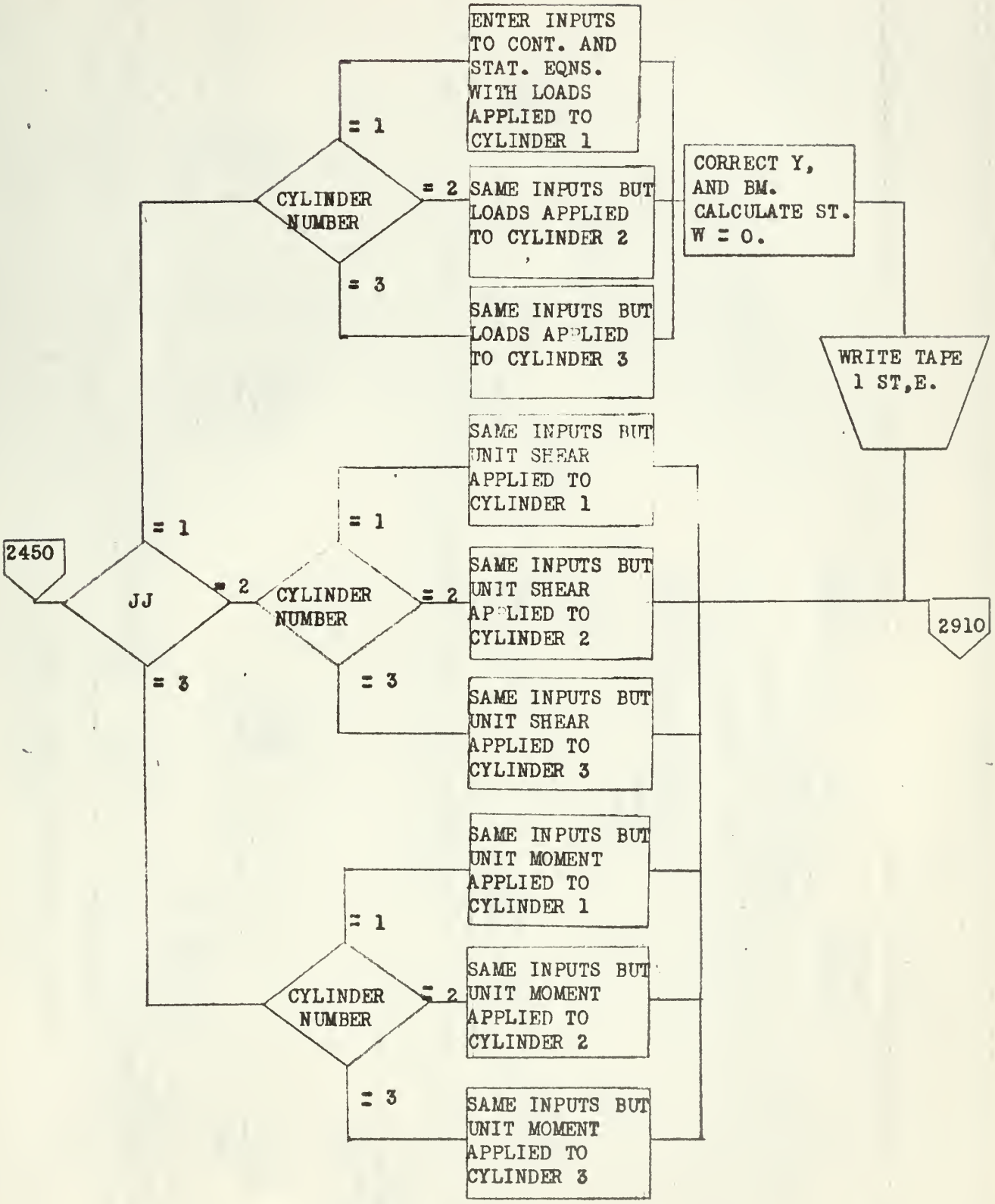
Subroutine GAUSS2 is not charted or listed because it is a standard library program for solution of simultaneous linear equations. The subroutine was written by C. B. Bailey and is listed in "F2 UTEX LINEQN," CO OP Manual for CDC 1604, December, 1960.

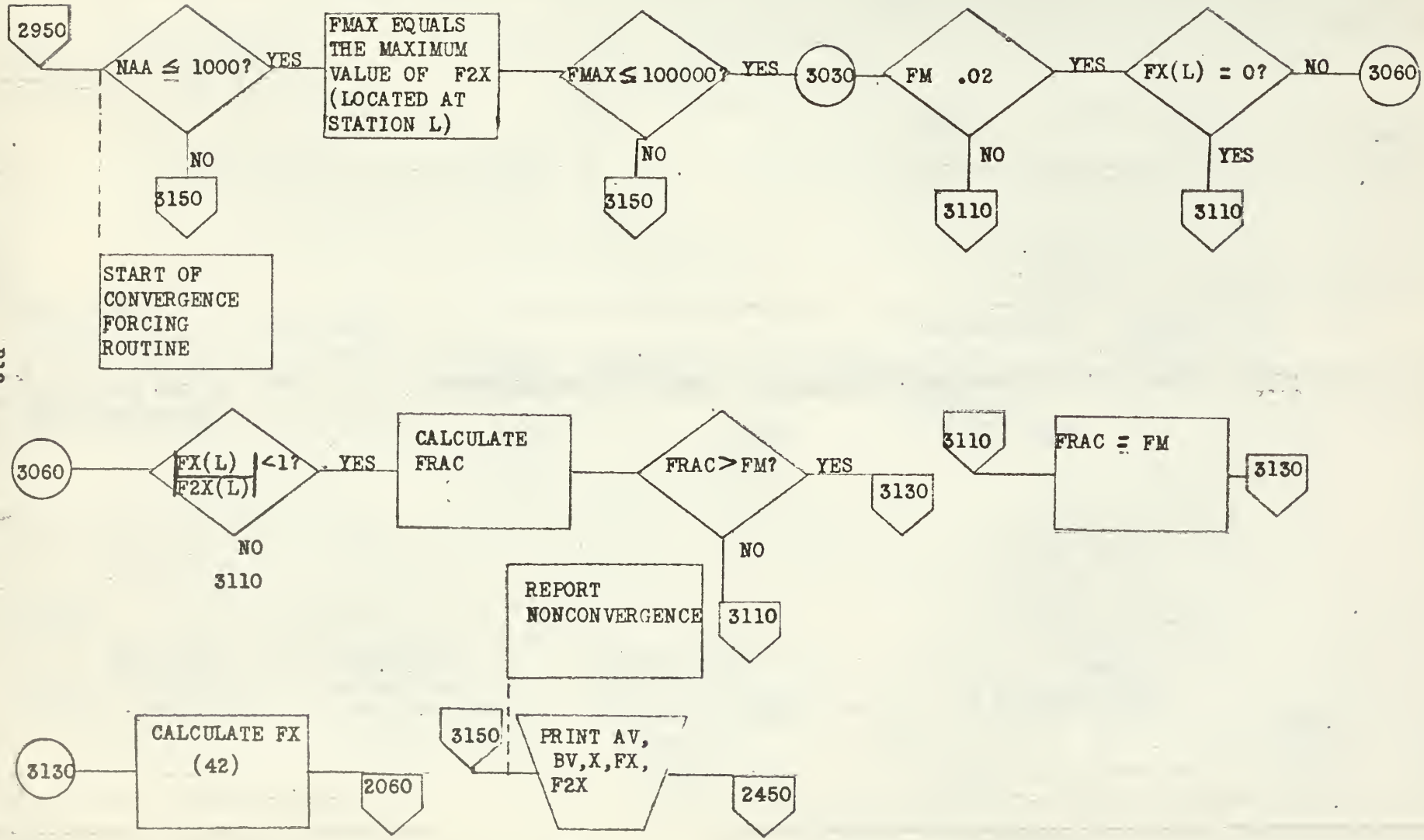

480
START
480
READ INSTRUCTIONS AND EXT. LOADS
PRINT EXPLANATION OF OUTPUT
550
SET-IN KNOWN INPUTS TO COMP. AND STAT. EQUATIONS (46)
740
740
READ IN CYLINDER PARAMETERS
940
SUBSTITUTE PARAMETERS OF PREVIOUS STATIONS FOR THOSE NOT GIVEN IN DATA
1120
PROGRAM STARTS TO DEAL WITH EACH CYLINDER INDIVIDUALLY
1120
READ IN CYLINDER LOADINGS
INTERPOLATE BETWEEN STATIONS WHOSE LOADS ARE GIVEN
1420
PRINT HEADING OF INPUT PRINTOUT
CYLINDER NUMBER 1?
YES
1600
NO
PRESSURE OPTION (IWILL)
= 2
READ R1, R2
1490
= 1
1600
1490
CALCULATE SIG1 AND SIG2 (51,51a)
PRINT R1 AND R2
1560
CALCULATE PRESSURE CONTRIBUTION TO COMPATIBILITY AND STATICS EQUATIONS. (52,53)
1660
1600
CALCULATE SIG1 AND SIG2 (51,51a)
1660
1660
PRINT CYLINDER PARAMETERS AND LOADS
CALCULATE C. C= 0 AT STATIONS WHERE CYLINDER IS SLOTTED
1760
CALCULATE EI,W,AMO, AND CX.
1870

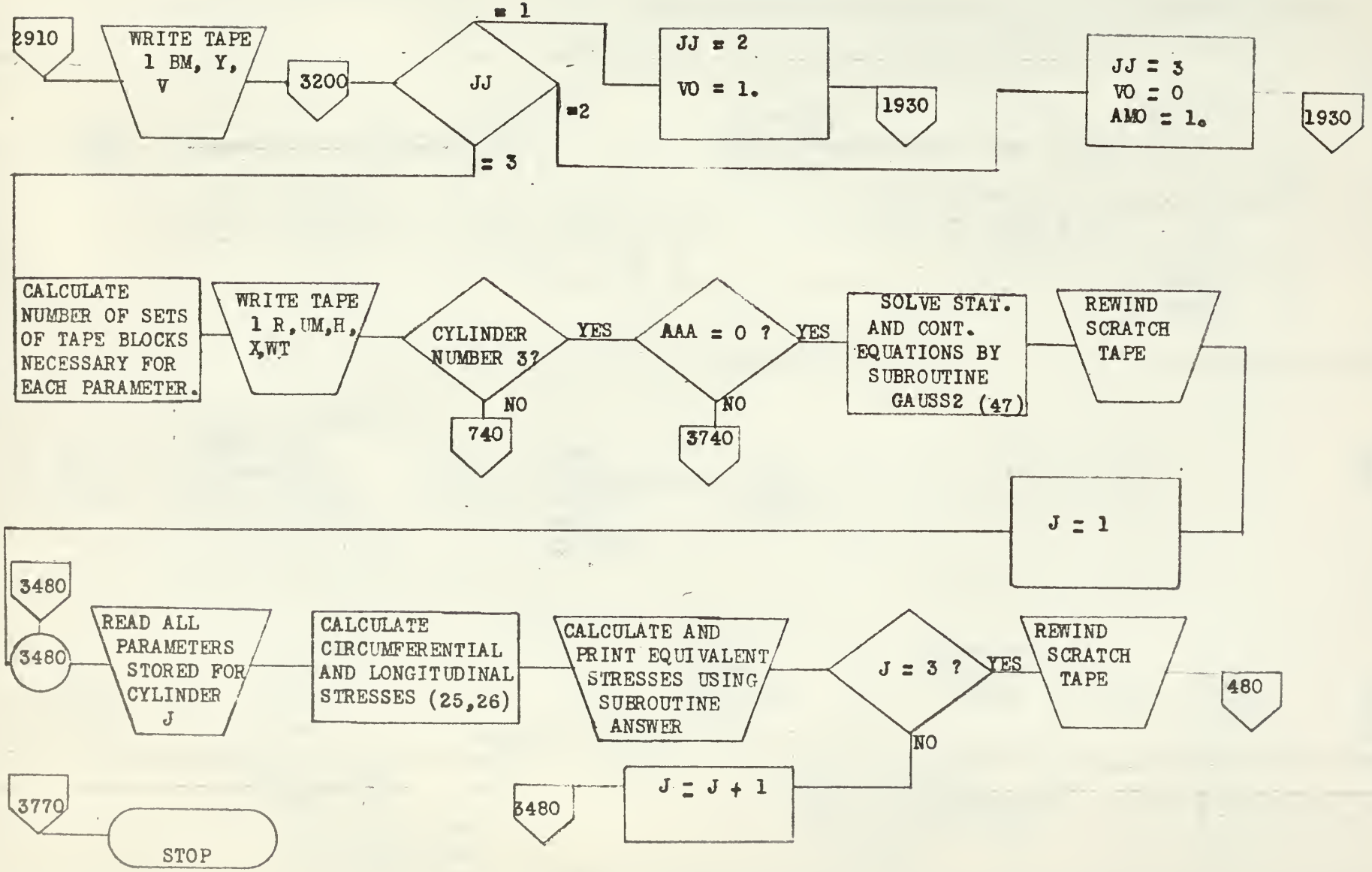


SKIRT (continued)

R10


2450
JJ
= 1
= 2
= 3
CYLINDER NUMBER
= 1
= 2
= 3
ENTER INPUTS TO CONT. AND STAT. EQNS. WITH LOADS APPLIED TO CYLINDER 1
SAME INPUTS BUT LOADS APPLIED TO CYLINDER 2
SAME INPUTS BUT LOADS APPLIED TO CYLINDER 3
CORRECT Y, AND BM. CALCULATE ST. W = 0.
WRITE TAPE 1 ST,E.
2910
CYLINDER NUMBER
= 1
= 2
= 3
SAME INPUTS BUT UNIT SHEAR APPLIED TO CYLINDER 1
SAME INPUTS BUT UNIT SHEAR APPLIED TO CYLINDER 2
SAME INPUTS BUT UNIT SHEAR APPLIED TO CYLINDER 3
CYLINDER NUMBER
= 1
= 2
= 3
SAME INPUTS BUT UNIT MOMENT APPLIED TO CYLINDER 1
SAME INPUTS BUT UNIT MOMENT APPLIED TO CYLINDER 2
SAME INPUTS BUT UNIT MOMENT APPLIED TO CYLINDER 3


2950
NAA ≤ 1000?
YES
NO
3150
FMAX EQUALS THE MAXIMUM VALUE OF F2X (LOCATED AT STATION L)
FMAX ≤ 100000?
YES
NO
3150
3030
FM .02
YES
NO
3110
FX(L) = 0?
NO
YES
3110
3060
START OF CONVERGENCE FORCING ROUTINE
3060
FX(L) / F2X(L) <1?
YES
NO
3110
CALCULATE FRAC
FRAC > FM?
YES
3130
NO
3110
REPORT NONCONVERGENCE
3110
FRAC = FM
3130
3130
CALCULATE FX (42)
2060
3150
PRINT AV, BV, X, FX, F2X
2450


2910
WRITE TAPE 1 BM, Y, V
3200
JJ
= 1
=2
= 3
JJ = 2
VO = 1.
1930
JJ = 3
VO = 0
AMO = 1.
1930
CALCULATE NUMBER OF SETS OF TAPE BLOCKS NECESSARY FOR EACH PARAMETER.
WRITE TAPE 1 R, UM, H, X, WT
CYLINDER NUMBER 3?
YES
NO
740
AAA = 0 ?
YES
NO
3740
SOLVE STAT. AND CONT. EQUATIONS BY SUBROUTINE GAUSS2 (47)
REWIND SCRATCH TAPE
J = 1
3480
3480
READ ALL PARAMETERS STORED FOR CYLINDER J
CALCULATE CIRCUMFERENTIAL AND LONGITUDINAL STRESSES (25,26)
CALCULATE AND PRINT EQUIVALENT STRESSES USING SUBROUTINE ANSWER
J = 3 ?
YES
NO
REWIND SCRATCH TAPE
480
3480
J = J + 1
3770
STOP

SUBROUTINE ZIGZAG

SUBROUTINE READ

SUBROUTINE ANSWER

```
      PROGRAM SKIRT                                                     SKCCC10
  100 FORMAT(4I5,6F10.0)                                                SK00020
  101 FORMAT (I5,5F15.0)                                                SK0003C
  102 FORMAT(I10,4F10.0)                                                SKCCC4C
  103 FORMAT(1H1, 48X,25HHOT SKIRT PROBLEM NUMBER ,I3/51X,15HCYLINDER NU SKC0050
     1MBER,I2///11H INPUT DATA,99(1H*))                                 SK00060
  104 FORMAT (5X,20HNUMBER OF INCREMENTS,I4,5X,9HMINIMUM X,1PE11.3,7H IN SK00C7C
     1CHES ,5X9HMAXIMUM X,E11.3,7H INCHES                               SKCCC8C
     1              /5X26HMOMENT APPLIED TO JUNCTION,E11.3,12H INCH POU SKCC090
     2NDS/5X30HSHEAR LOAD APPLIED TO JUNCTION,E11.3,7H POUNDS/5X16HCYLIN SK00100
     3DER SLOTTED8H FROM X=,E11.3,6H TO X=,E11.3/5X6CHFRACTION OF MAXIMU SK00110
     4M DISTORTION USED AS CONVERGENCE CRITERION,E9.2/                  SKC0120
     55X,8HEXPONENT ,I4/5X28HMINIMUM CONVERGENCE FRACTION ,E9.2 )       SK00125
  105 FORMAT(//20H CYLINDER PARAMETERS//4H STA10X1HX5X6HYOUNGS14X8HPOISS SK00130
     1ONS7X4HWALL4X7HTHERMAL5X6HMEDIAN5X6HRADIAL6X5HAXIAL          /4H  SK00140
     2NC3X8HLOCATICN4X7HMODULUS5X6HRADIUS6X5HRATIO2X9HTHICKNESS6X5HCOEFF SKC0150
     37X4HTEMP2X9HTEMP CIFF7X4HLOAD)                                    SK00160
  106 FORMAT (I4,10(1PE11.3))                                           SK00170
  113 FORMAT(21H NUMBER OF ITERATIONS  , I4)                            SK00180
  114 FORMAT(/////8H RESULTS,1C3(1H*)//16HDID NOT CONVERGE)             SK00190
  115 FORMAT (5X,3HA= ,1PE11.3,5X,3HB= ,1PE11.3)                        SK00200
  116 FORMAT (15X,10HX LOCATION,18X,2HFX,17X,3HF1X,17X,3HF2X)           SK00210
  118 FORMAT(5X,4(1PE20.3))                                             SKCC220
  119 FORMAT(1H1)                                                       SKCC230
  120 FORMAT(/5X 87HSTRESSES DUE TO PRESSURE IN VESSEL ARE CALCULATED US SK00240
     1ING OPTION 1.                                                     SK00250
     6//5X17HINTERNAL PRESSURE   ,1PE11.3  ,4H PSI  )                   SKC0260
  121 FORMAT(/5X56HSTRESSES DUE TC PRESSURE ARE CALCULATED USING CPTION  SKCC270
     22.  /56H     R1 IS THE RADIUS OF THE MERIDIAN AT THE JUNCTION.    SKC0280
     3              /5X106HR2 IS RADIUS OF CIRCUMFERENCE AT JUNCTION,   SK00290
     3 DIVIDED BY THE COSINE OF THE ANGLE BETWEEN THE TANGENT TO THE   / SKC0300
     410X22HMERIDIAN AND THE AXIS.                                      SKC0310
     6              //5X17HINTERNAL PRESSURE  ,1PE11.3, 4H PSI)        SK00320
  122 FORMAT(2F10.0)                                                    SK0033C
  123 FORMAT (5X3HR1=,1PE11.3,5H, R2=E11.3)                             SKC0340
  124 FORMAT (5X19HR1 IS INFINITE, R2=1PE11.3)                          SKC0350
  145 FORMAT(2I10,3F10.0,I10,F10.0)                                     SK00360
      DIMENSION X(201),W(201),C(201),EI(201),Q(201),V(201),BM(201),CX(20 SK00370
     11),FX(201),SL(201),Y(201),C1(201),C2(201),CX1(201),CX2(201      SK00380
     2),W1(201),W2(201),FXC(201),FXC1(201),FXC2(201),VBAR(201),VBAR1(201 SK00390
     3),AMBAR(201),F1X(201),CURVE(201),F2X(201),TL(201),E(201),R(201),TR SK00400
     4(201),UM(201),H(201),AL(201),A(6,7),B(6,1),AX(6,1),INC(3),TP(3),  SK0041C
     5SLOT(3),SLOT1(3),WT(201),SIG1(3),SIG2(3),PSI1(3)                  SK00420
      DIMENSION ST(201),Y1(201),Y2(201),Y3(201),V1(201),V2(201),V3(201), SK00430
     1BM1(201),BM2(201),BM3(201),STLO(201),STLI(201),STCO(201),STCI(201) SK00440
      EQUIVALENCE (TL,ST),(Y,Y1),(C2,Y2),(CX1,Y3),(V,V1),(VBAR,V2)   ,  SK0045C
     1(VBAR1,V3),(BM,BM1),(CX,BM2),(CX2,BM3),(STLO,W),(STLI,Q),(STCO,C), SK00460
     2(STCI,EI)                                                         SK00470
 4000 READ 145 IPROB,IIF,AM00,V00,PSI,IWILL,FM                          SK00480
      IF (IPROB) 4001,4002,4001                                         SK0049C
 4001 CONTINUE                                                          SK00500
```

```
      AAA=0.                                                                    SK00501
      IF(FM)   4035,4035,4036                                                   SK00503
 4035 FM=.06                                                                    SK00506
 4036 CALL PRINT    (IPROB)                                                     SK00510
      DO 4022 I=1,6                                                             SK00520
      B(I,1)=0.                                                                 SK00530
      DO 4022 J=1,7                                                             SK00540
 4022 A(I,J)=0.                                                                 SK00550
      A(1,1)=1.                                                                 SK00560
      A(1,2)=1.                                                                 SK00570
      A(1,3)=1.                                                                 SK00580
      A(1,4)=0                                                                  SK00590
      A(1,5)=0                                                                  SK00600
      A(1,6)=0                                                                  SK00610
      A(2,1)=0                                                                  SK00620
      A(2,2)=0                                                                  SK00630
      A(2,3)=0                                                                  SK00640
      A(2,4)=1.                                                                 SK00650
      A(2,5)=1.                                                                 SK00660
      A(2,6)=1.                                                                 SK00670
      B(1,1)=V00                                                                SK00680
      B(2,1)=AM00                                                               SK00690
      IF (IWILL-1) 7001,7001,7000                                               SK00700
 7000 PRINT 121  PSI                                                            SK00710
      GO TO 1                                                                   SK00720
 7001 PRINT 120 PSI                                                             SK00730
    1 READ 100 ICYL,(INC(ICYL),INC,IEXP,XMIN,XMAX,ERROR,SLOT1(ICYL)             SK00740
     1,SLOT(ICYL))                                                              SK00750
      IF(IEXP) 342,342,341                                                      SK00760
  342 IEXP=11                                                                   SK00770
  341 AINC=INC(ICYL)                                                            SK00780
      XDEL=(XMAX-XMIN)/AINC                                                     SK00790
      XDEL2=XDEL*.5                                                             SK00800
      INC2=INC(ICYL)*2+1                                                        SK00810
      X(1)=XMIN                                                                 SK00820
      DO 200 I=2,INC2,1                                                         SK00830
  200 X(I)=X(I-1)+XDEL2                                                         SK00840
      DO 251 I=1,INC2                                                           SK00850
      E(I)=0.                                                                   SK00860
      R(I)=0.                                                                   SK00870
      UM(I)=0.                                                                  SK00880
      H(I)=0.                                                                   SK00890
  251 AL(I)=0.                                                                  SK00900
  250 READ 101 J,(E(2*J-1),R(2*J-1),UM(2*J-1),H(2*J-1),AL(2*J-1))               SK00910
      I=2*J-1                                                                   SK00920
      IF(I-INC2) 250,252,252                                                    SK00930
  252 DO 253 I=3,INC2,2                                                         SK00940
      IF (E(I)) 371,370,371                                                     SK00950
  370 E(I)=E(I-2)                                                               SK00960
  371 IF (R(I))373,372,373                                                      SK00970
  372 R(I)=R(I-2)                                                               SK00980
  373 IF (UM(I)) 375,374,375                                                    SK00990
  374 UM(I)=UM(I-2)                                                             SK01000
```

```
  375 IF (H(I))  377,376,377                                                    SK01010
  376 H(I)=H(I-2)                                                               SK01020
  377 IF(AL(I)) 253,378,253                                                     SK01030
  378 AL(I)=AL(I-2)                                                             SK01040
  253 CONTINUE                                                                  SK01050
      IF (IND) 4202,4202,4201                                                   SK01060
 4202 IND =1                                                                    SK01070
 4201 IND=IND*2                                                                 SK01080
      DO 2000 I=1,INC2                                                          SK01090
      TL(I)=0.                                                                  SK01100
 2000 TR(I)=0.                                                                  SK01110
 2001 READ 102 J,(TL(2*J-1),TR(2*J-1),WT(2*J-1))                                SK01120
      I=2*J-1                                                                   SK01130
      IF (TL(I)) 4101,3002,4101                                                 SK01140
 3002 TL(I)=.0000000001                                                         SK01150
 4101 IF (I-INC2) 2001,2002,2002                                                SK01160
 2002 K2=1                                                                      SK01170
 2003 DO 2004 I=K2,INC2,2                                                       SK01180
      IF(TL(I)) 2004,3005,2004                                                  SK01190
 3005 K1=I                                                                      SK01200
      DO 2006 J=K1,INC2,2                                                       SK01210
      IF (TL(J)) 3006,2006,3006                                                 SK01220
 3006 K2=J                                                                      SK01230
      GO TO 3007                                                                SK01240
 2006 CONTINUE                                                                  SK01250
 2004 CONTINUE                                                                  SK01260
      GO TO 3008                                                                SK01270
 3007 K3=(K2-K1+2)/2                                                            SK01280
      AK3=K3                                                                    SK01290
      TLINC=(TL(K2)-TL(K1-2))/AK3                                               SK01300
      TRINC=(TR(K2)-TR(K1-2))/AK3                                               SK01310
      WTINC=(WT(K2)-WT(K1-2))/AK3                                               SK01320
      DO 2005 I=K1,K2,2                                                         SK01330
      TL(I)=TL(I-2)+TLINC                                                       SK01340
      WT(I)=WT(I-2)+WTINC                                                       SK01350
 2005 TR(I)=TR(I-2)+TRINC                                                       SK01360
      GO TO 2003                                                                SK01370
 3008 DO 3013 I=1,INC2,2                                                        SK01380
      IF(TL(I)-.0000000001) 3013,3014,3013                                      SK01390
 3014 TL(I)=0.                                                                  SK01400
 3013 CONTINUE                                                                  SK01410
      PRINT 103 IPRCB,ICYL                                                      SK01420
      PRINT104INC(ICYL),XMIN,XMAX,AMOO,VOO,SLOT1(ICYL),SLOT(ICYL),ERROR         SK01430
     1,IEXP,FM                                                                  SK01435
      IF (ICYL-1) 7002,7002,7003                                                SK01440
 7003 IF(IWILL-1) 7002,7002,7004                                                SK01450
 7004 READ 122 R1,R2                                                            SK01460
      IF (R2) 7005,7006,7005                                                    SK01470
 7006 R2=R(1)                                                                   SK01480
 7005 SIG1(ICYL)=PSI*R2/(2.*H(1))                                               SK01490
      IF(R1) 7013,7014,7013                                                     SK01500
```

```
7013 PRINT 123 R1,R2                                                    SK01510
     SIG2(ICYL)=(PSI/H(1)-SIG1(ICYL)/R1)*R2                             SK01520
     GO TO 7009                                                         SK01530
7014 PRINT 124 R2                                                       SK01540
7008 SIG2(ICYL)= (PSI/H(1))*R2                                          SK01550
7009 B(ICYL+3,1)=(R(1)/E(1))*(SIG2(ICYL)-UM(1)*SIG1(ICYL))              SK01560
     B(1,1)=(-(R2*R2-R(1)*R(1))**.5)*SIG1(ICYL)/R(1)+B(1,1)             SK01570
     PSI1(ICYL)=0.                                                      SK01580
     GO TO 7012                                                         SK01590
7002 SIG1(ICYL)=PSI*R(1)/(2.*H(1))                                      SK01600
     SIG2(ICYL)=2.*SIG1(ICYL)                                           SK01610
     SIG1(1)=0.                                                         SK01620
     SIG2(1)=0.                                                         SK01630
     PSI1(ICYL)=PSI                                                     SK01640
     PSI1(1)=0.                                                         SK01650
7012 PRINT 105                                                          SK01660
     DO 6007 I=1,INC2,IND                                               SK01670
     II=(I+1)/2                                                         SK01680
6007 PRINT106II,X(I),E(I),R(I),UM(I),H(I),AL(I),TL(I),TR(I),WT(I)       SK01690
     DO 254 I=1,INC2,2                                                  SK01700
     IF(X(I)-SLOT1(ICYL)) 286,286,285                                   SK01710
 285 IF(X(I)-SLOT(ICYL))288,286,286                                     SK01720
 288 C(I)=0                                                             SK01730
     GO TO 287                                                          SK01740
 286 C(I)=(E(I)*H(I))/(R(I)*R(I))                                       SK01750
 287 EI(I)=(E(I)*H(I)*H(I)*H(I))/(12.*(1.-UM(I)*UM(I)))                 SK01760
 254 W(I)=C(I)*(TL(I)-TL(1))*AL(I)*R(I)+PSI1(ICYL)*(1.-.5*UM(I))        SK01770
    1-UM(I)*WT(I)/(E(I)*6.2832      *H(I))*C(I)                         SK01780
     AMO=E(1)*TR(1)*(H(1)**2)*AL(1)/(12.*(1.-UM(1)))                    SK01800
     AML=0                                                              SK01810
     VO=0                                                               SK01820
     VL=0                                                               SK01830
     JJ=1                                                               SK01840
     DO 290 I=1,INC2                                                    SK01850
 290 CX(I) = C(I)*X(I)                                                  SK01860
     AA=1.                                                              SK01870
     CALL ZIGZAG(AA,XDEL,INC2,C,C1)                                     SK01880
     CALL ZIGZAG(AA,XDEL,INC2,CX,CX1)                                   SK01890
     AA=2.                                                              SK01900
     CALL ZIGZAG(AA,XDEL,INC2,C1,C2)                                    SK01910
     CALL ZIGZAG(AA,XDEL,INC2,CX1,CX2)                                  SK01920
   4 DO 257 I=1,INC2                                                    SK01930
     VBAR(I)=VO                                                         SK01940
 257 AMBAR(I)=AMO                                                       SK01950
     DO 273 I=3,INC2,2                                                  SK01960
 273 AMBAR(I)=AMBAR(I-2)+(TR(I)-TR(I-2))*E(I)*(H(I)**2)*AL(I)/(12.*(1.- SK01970
    1UM(I)))                                                            SK01975
     AA=1.                                                              SK01980
     CALL ZIGZAG(AA,XDEL,INC2,W,W1)                                     SK01990
     AA=2.                                                              SK02000
```

```
      CALL ZIGZAG(AA,XDEL,INC2,VBAR,VBAR1)                                  SK02010
      CALL ZIGZAG(AA,XDEL,INC2,W1,W2)                                       SK02020
    3 NAA=0                                                                 SK02030
      DO 221 I=1,INC2,2                                                     SK02040
  221 FX(I)=0.                                                              SK02050
    2 NAA=NAA+1                                                             SK02060
      DO 207 I=1,INC2,2                                                     SK02070
  207 FXC(I)=FX(I)*C(I)                                                     SK02080
      AA=1.                                                                 SK02090
      CALL ZIGZAG(AA,XDEL,INC2,FXC,FXC1)                                    SK02100
      AA=2.                                                                 SK02110
      CALL ZIGZAG(AA,XDEL,INC2,FXC1,FXC2)                                   SK02120
      AV=((VBAR(INC2)-VL-FXC1(INC2)+W1(INC2))*(CX2(INC2))-(CX1(INC2))*      SK02130
     1(AMBAR(INC2)-AML+VBAR1(INC2)-FXC2(INC2)+W2(INC2)))/((C1(INC2))*       SK02140
     2(CX2(INC2))-(CX1(INC2))*(C2(INC2)))                                   SK02150
      BV=((C1(INC2))*(AMBAR(INC2)-AML+VBAR1(INC2)-FXC2(INC2)+W2(INC2))      SK02160
     1-(VBAR(INC2)-VL-FXC1(INC2)+W1(INC2))*(C2(INC2)))/((C1(INC2))*(CX2     SK02170
     2(INC2))-(CX1(INC2))*(C2(INC2)))                                       SK02180
      DO 208 I=1,INC2,2                                                     SK02190
      BM(I)=(AMBAR(I)+VBAR1(I)-AV*C2(I)-BV*CX2(I)-FXC2(I)+W2(I))            SK02200
  208 CURVE(I)=BM(I)/EI(I)                                                  SK02210
      AA=1.                                                                 SK02220
      CALL ZIGZAG(AA,XDEL,INC2,CURVE,GX)                                    SK02230
      AA=2.                                                                 SK02240
      CALL ZIGZAG(AA,XDEL,INC2,GX,F1X)                                      SK02250
      FF=F1X(INC2)/XMAX                                                     SK02260
      DO 212 I=1,INC2,2                                                     SK02270
  212 F2X(I) =F1X(I) -FF*X(I)                                               SK02280
      YMAX =0.                                                              SK02290
      LL=1                                                                  SK02300
      DO 209 I=1,INC2,2                                                     SK02310
      Y(I)=AV+BV*X(I)+F2X(I)                                                SK02320
      IF (ABSF(Y(I))-YMAX)209,209,306                                       SK02330
  306 YMAX=ABSF(Y(I))                                                       SK02340
      LL=I                                                                  SK02350
  209 CONTINUE                                                              SK02360
      YMAX1=ERROR*YMAX                                                      SK02370
      DO 255 I=1,INC2,2                                                     SK02380
      IF (ABSF(F2X(I)-FX(I))-YMAX1) 255,255,309                             SK02390
  255 CONTINUE                                                              SK02400
      PRINT 113 NAA                                                         SK02410
      DO 202 I=1,INC2                                                       SK02420
      V(I)=       VBAR(I)-AV*C1(I)-BV*CX1(I)-FXC1(I)+W1(I)                  SK02430
  202 SL(I)=BV+GX(I)-FF                                                     SK02440
 4320 IF(JJ-2) 1001,1002,1003                                               SK02450
 1001 IF(ICYL-2) 1100,1101,1102                                             SK02460
 1100 B(3,1)=SL(1)+B(3,1)                                                   SK02470
      B(4,1)=SL(1)+B(4,1)                                                   SK02480
      B(5,1)=-Y(1) +B(5,1)                                                  SK02490
      B(6,1)=-Y(1)  +B(6,1)                                                 SK02500
```

```
      GO TO 4302                                                        SK02510
 1101 B(3,1)=B(3,1)-SL(1)                                               SK02520
      B(5,1)=B(5,1)+Y(1)                                                SK02530
      GO TO 4302                                                        SK02540
 1102 B(4,1)=B(4,1)+SL(1)                                               SK02550
      B(6,1)=B(6,1)+Y(1)                                                SK02560
      GO TO 4302                                                        SK02570
 4302 DO 256 I=1,INC2                                                   SK02580
       Y(I)=Y(I)-W(I)/C(I)                                              SK02590
      ST(I)=E(I)*AL(I)*TR(I)/2.                                         SK02600
      BM(I)=BM(I)-E(I)*TR(I)*(H(I)**2)*AL(I)/(12.*(1.-UM(I)))           SK02610
  256 W(I)=0.                                                           SK02620
      AMO=0.                                                            SK02630
      WRITE TAPE 1 (ST(I) I=1,INC2)                                     SK02640
      WRITE TAPE 1 (E(I) I=1,INC2)                                      SK02650
      GO TO 5                                                           SK02660
 1002 IF (ICYL-2) 1103,1104,1105                                        SK02670
 1103 A(3,1)=-SL(1)                                                     SK02680
      A(4,1)=-SL(1)                                                     SK02690
      A(5,1)=Y(1)                                                       SK02700
      A(6,1)=Y(1)                                                       SK02710
      GO TO 5                                                           SK02720
 1104 A(3,2)=SL(1)                                                      SK02730
      A(5,2)=-Y(1)                                                      SK02740
      GO TO 5                                                           SK02750
 1105 A(4,3)=-SL(1)                                                     SK02760
      A(6,3)=-Y(1)                                                      SK02770
      GO TO 5                                                           SK02780
 1003 IF (ICYL-2) 1106,1107,1108                                        SK02790
 1106 A(3,4)=-SL(1)                                                     SK02800
      A(4,4)=-SL(1)                                                     SK02810
      A(5,4)=Y(1)                                                       SK02820
      A(6,4)=Y(1)                                                       SK02830
      GO TO 5                                                           SK02840
 1107 A(3,5)=SL(1)                                                      SK02850
      A(5,5)=-Y(1)                                                      SK02860
      GO TO 5                                                           SK02870
 1108 A(4,6)=SL(1)                                                      SK02880
      A(6,6)=Y(1)                                                       SK02890
      GO TO 5                                                           SK02900
    5 WRITE TAPE 1, (BM(I) I=1,INC2)                                    SK02910
      WRITE TAPE 1 (Y(I) I=1,INC2)                                      SK02920
      WRITE TAPE 1 ( V(I) I=1,INC2)                                     SK02930
      GO TO 350                                                         SK02940
  309 IF(NAA-1000) 360,360,352                                          SK02950
  360 FMAX=ABSF(F2X(1))                                                 SK02960
      L=1                                                               SK02970
      DO 211 I=1,INC2,2                                                 SK02980
      IF (FMAX-ABSF(F2X(I))) 331,331,211                                SK02990
  331 FMAX=ABSF(F2X(I))                                                 SK03000
```

```
      L=I                                                                    SK03010
      IF (FMAX-100000.) 211,352,352                                          SK03015
  211 CONTINUE                                                               SK03020
      IF (FM-.02) 339,339,397                                                SK03030
  397 IF (FX(L)/FMAX) 333,339,333                                            SK03040
  333 IF(ABSF(FX(L)/FMAX)-1.) 336,336,337                                    SK03060
  336 FRAC=ABSF(FX(L)/FMAX)**IEXP                                            SK03070
      GO TO 338                                                              SK03080
  337 FRAC =FM                                                               SK03090
  338 IF (FRAC-FM) 339,335,335                                               SK03100
  339 FRAC =FM                                                               SK03110
  335 DO 213 I=1,INC2,2                                                      SK03120
  213 FX(I) =FRAC*F2X(I) +(1.-FRAC)*FX(I)                                    SK03130
      GO TO 2                                                                SK03140
  352 PRINT 114                                                              SK03150
      PRINT 115 AV,BV                                                        SK03160
      PRINT 116                                                              SK03170
      PRINT 118 (X(I),FX(I),F1X(I),F2X(I),I=1,INC2,IND)                      SK03180
      AAA=1.                                                                 SK03185
      GO TO 4320                                                             SK03190
  350 IF(JJ-2)1004,1005,1006                                                 SK03200
 1004 JJ=2                                                                   SK03210
      AII=1.                                                                 SK03220
      VO=1.                                                                  SK03230
      GO TO 4                                                                SK03240
 1005 VO=0                                                                   SK03250
      AMO=1.                                                                 SK03260
      JJ=3                                                                   SK03270
      GO TO 4                                                                SK03280
 1006 INC21=INC2                                                             SK03290
      DO 1109 I=1,9                                                          SK03300
      IF (INC21-53) 1110,1110,1109                                           SK03310
 1110 TP(ICYL)=I                                                             SK03320
      WRITE TAPE 1 (R(I) I=1,INC2)                                           SK03330
      WRITE TAPE 1 (UM(I) I=1,INC2)                                          SK03340
      WRITE TAPE 1 (H(I) I=1,INC2)                                           SK03350
      WRITE TAPE 1(X(I) I=1,INC2)                                            SK03360
      WRITE TAPE 1(WT(I) I=1,INC2)                                           SK03370
      GO TO 1111                                                             SK03380
 1109 INC21=INC21-53                                                         SK03390
  351 CONTINUE                                                               SK03400
 1111 IF(ICYL-3) 1,351,351                                                   SK03410
      IF (AAA-1.)  4038,4037,4037                                            SK03415
 4038 CALL GAUSS2 (6,1,.000001,A,B,AX,KER)                                   SK03420
      TPI=16.*(TP(1)+TP(2)+TP(3))                                            SK03430
      ITP= TPI                                                               SK03440
      DO 1120 I=1,ITP                                                        SK03450
 1120 BACKSPACE 1                                                            SK03460
      AX(6)=-AX(6)                                                           SK03470
      DO 1123 J=1,3                                                          SK03480
      INC2=INC(J)*2+1                                                        SK03490
      CALL READ(J,Y1,Y2,Y3,V1,V2,V3,BM1,BM2,BM3,R,UM,H,X,INC,WT,E,ST)        SK03500
```

```
      DO 1122 I=1,INC2,2                                                        SK03510
      Y(I)=Y1(I)+AX(J)*Y2(I)+AX(J+3)*Y3(I)                                      SK03520
      V(I) =V1(I)+V2(I)*AX(J)+V3(I)*AX(J+3)                                     SK03530
      BM(I)=BM1(I)+BM2(I)*AX(J)+BM3(I)*AX(J+3)                                  SK03540
      STLO(I)=-6.*BM(I)/(H(I)*H(I))                                             SK03550
      STLI(I)=-STLO(I)                                                          SK03560
      IF (X(I)-SLOT1(J)) 6001,6001,6000                                         SK03570
 6000 IF(X(I)-SLOT(J)) 6002,6001,6001                                           SK03580
 6002 STCO(I)=UM(I)*STLO(I)+ST(I)                                               SK03590
      STCI(I)=-STCO(I)                                                          SK03600
      STLO(I)=STLO(I)+SIG1(J)*R(I)*H(1)/(R(1)*H(I))+WT(I)/(6.2832*R(I)*         SK03610
     1H(I))                                                                     SK03620
      STLI(I)=STLO(I)+2.*STLI(I)                                                SK03630
      GO TO 1122                                                                SK03640
 6001 STCO(I)=Y(I)*E(I)/R(I)+UM(I)*STLO(I)+ST(I)                                SK03650
     1+SIG2(J)*R(I)*H(1)/(R(1)*H(I))                                            SK03660
      STCI(I)=STCO(I)-(UM(I)*STLO(I)+ST(I))*2.                                  SK03670
      STLO(I)=STLO(I)+SIG1(J)*R(I)*H(1)/(R(1)*H(I))+WT(I)/(6.2832*R(I)*         SK03680
     1H(I))                                                                     SK03690
      STLI(I)=STLO(I)+2.*STLI(I)                                                SK03700
 1122 CONTINUE                                                                  SK03710
      CALL ANSWER (STLO,STLI,STCO,STCI,X,J,INC,IIF,IPROB,BM,V)                  SK03720
 1123 CONTINUE                                                                  SK03730
 4037 DO 4020 I=1,ITP                                                           SK03740
 4020 BACKSPACE 1                                                               SK03750
      GO TO 4000                                                                SK03760
 4002 PRINT 119                                                                 SK03770
      STOP                                                                      SK03780
       END                                                                      SK03790
```

```
      SUBROUTINE ZIGZAG (A,B,M,D,E)                                     SK03800
      DIMENSION  D(201),E(201)                                          SK03810
      E(1)=0.                                                           SK03820
      IF (A-1.) 1,1,2                                                   SK03830
    1 E(2)=((3.*D(1)+D(3))/8.)*B                                        SK03840
      II=4                                                              SK03850
      GO TO 3                                                           SK03860
    2 II=3                                                              SK03870
    3 DO 4 I=II,M,2                                                     SK03880
    4 E(I)=E(I-2)+D(I-1)*B                                              SK03890
      IF (A-1.) 5,5,6                                                   SK03900
    5 E(M)=E(M-1)+((D(M-2)*3.+D(M))/8.)*B                               SK03910
    6 RETURN                                                            SK03920
      END                                                               SK03930
```

```
      SUBROUTINE READ (J,Y1,Y2,Y3,V1,V2,V3,BM1,BM2,BM3,R,UM,H,X,INC,WT,  SK03940
     1E,ST)                                                             SK03950
      DIMENSION Y1(201),Y2(201),Y3(201),V1(201),V2(201),V3(201),BM1(201) SK03960
     1,BM2(201),BM3(201),R(201),UM(201),H(201),X(201),INC(3),WT(201),E(2 SK03970
     201),ST(201)                                                       SK03980
      INC2=INC(J)*2+1                                                   SK03990
    1 FORMAT(I20)                                                       SK04000
      READ TAPE 1 (ST(I) I=1,INC2)                                      SK04010
      READ TAPE 1 (E(I) I=1,INC2)                                       SK04020
      READ TAPE 1 (BM1(I) I=1,INC2)                                     SK04030
      READ TAPE 1 (Y1(I) I=1,INC2)                                      SK04040
      READ TAPE 1 (V1(I) I=1,INC2)                                      SK04050
      READ TAPE 1 (BM2(I) I=1,INC2)                                     SK04060
      READ TAPE 1 (Y2(I) I=1,INC2)                                      SK04070
      READ TAPE 1 (V2(I) I=1,INC2)                                      SK04080
      READ TAPE 1 (BM3(I) I=1,INC2)                                     SK04090
      READ TAPE 1 (Y3(I) I=1,INC2)                                      SK04100
      READ TAPE 1 (V3(I) I=1,INC2)                                      SK04110
      READ TAPE 1 (R(I) I=1,INC2)                                       SK04120
      READ TAPE 1 (UM(I) I=1,INC2)                                      SK04130
      READ TAPE 1 (H(I) I=1,INC2)                                       SK04140
      READ TAPE 1 (X(I) I=1,INC2)                                       SK04150
      READ TAPE 1 (WT(I) I=1,INC2)                                      SK04160
      INC22=INC2-2                                                      SK04170
      DO 1121 I=3,INC22,2                                               SK04180
      V1(I)=(V1(I-1)+V1(I+1))/2.                                        SK04190
      V2(I)=(V2(I-1)+V2(I+1))/2.                                        SK04200
 1121 V3(I)=(V3(I-1)+V3(I+1))/2.                                        SK04210
      RETURN                                                            SK04220
      END                                                               SK04230
```

```
      SUBROUTINE GAUSS2(N,M,EP,A,B,X,KER)                               SK04240
      DIMENSION A(6,7),B(6,1),X(6,1)                                    SK04250
       NPM=N+M                                                          SK04260
      DO 2 K = 1,M                                                      SK04270
      I = N+K                                                           SK04280
      DO 2 J = 1,N                                                      SK04290
    2 A(J,I) = B(J,K)                                                   SK04300
   10  DO 34 L=1,N                                                      SK04310
       KP=0                                                             SK04320
       Z=0.0                                                            SK04330
       DO 12 K=L,N                                                      SK04340
       IF(Z-ABSF(A(K,L)))11,12,12                                       SK04350
   11  Z=ABSF(A(K,L))                                                   SK04360
       KP=K                                                             SK04370
   12  CONTINUE                                                         SK04380
       IF(L-KP)13,20,20                                                 SK04390
   13  DO 14 J=L,NPM                                                    SK04400
       Z=A(L,J)                                                         SK04410
       A(L,J)=A(KP,J)                                                   SK04420
   14  A(KP,J)=Z                                                        SK04430
   20  IF(ABSF(A(L,L))-EP)50,50,30                                      SK04440
   30  IF(L-N)31,40,40                                                  SK04450
   31  LP1=L+1                                                          SK04460
       DO 34 K=LP1,N                                                    SK04470
       IF(A(K,L))32,34,32                                               SK04480
   32  RATIO=A(K,L)/A(L,L)                                              SK04490
       DO 33 J=LP1,NPM                                                  SK04500
   33  A(K,J)=A(K,J)-RATIO*A(L,J)                                       SK04510
   34  CONTINUE                                                         SK04520
   40  DO 43 I=1,N                                                      SK04530
       II=N+1-I                                                         SK04540
       DO 43 J=1,M                                                      SK04550
       JPN=J+N                                                          SK04560
       S=0.0                                                            SK04570
       IF(II-N)41,43,43                                                 SK04580
   41  IIP1=II+1                                                        SK04590
       DO 42 K=IIP1,N                                                   SK04600
   42  S=S+A(II,K)*X(K,J)                                               SK04610
   43  X(II,J)=(A(II,JPN)-S)/A(II,II)                                   SK04620
       KER=1                                                            SK04630
      RETURN                                                            SK04640
   50 KER = 2                                                           SK04650
      END                                                               SK04660
```

```
      SUBROUTINE PRINT    (IPRCB)                                                  SK04670
    6 FORMAT(1H1,11X,21HHOT SKIRT PROBLEM NO.    ,I3)                            SK04680
    1 FORMAT     (              47X23HEXPLANATION OF PRINTOUT//30X59HUNIT        SK04690
     1S  (ENGLISH SYSTEM. ANY CONSISTENT SYSTEM SATISFACTORY)/                    SK04700
     236X10HX (INCHES)20X23HWALL THICKNESS (INCHES)/                             SK04710
     331X20HMOMENT (INCH-POUNDS)15X21HPOISSONS RATIO (NONE)/                     SK04720
     427X19HSHEAR LOAD (POUNDS) 28X15HRADIUS (INCHES)/                           SK04730
     523X35HYOUNGS MODULUS (POUNDS/SQUARE-INCH)4X30HMEDIAN TEMPERATURE (         SK04740
     6DEGREES F)/                                                                SK04750
     75X56HTHERMAL COEFFICIENT OF EXPANSION (INCHES/INCH-DEGREE F)               SK04760
     811X19HAXIAL LOAD (POUNDS))                                                 SK04770
    2 FORMAT (8X41HRADIAL TEMPERATURE DIFFERENCE (DEGREES F)                     SK04780
     125X29HPRESSURE (POUNDS/SQUARE-INCH)/                                       SK04790
     229X29HSTRESSES (POUNDS/SQUARE-INCH)//)                                     SK04800
    3 FORMAT(51X16HSIGN CONVENTIONS/                                             SK04810
     138X34HX -DISTANCE MEASURED FROM JUNCTION/                                  SK04820
     25X53HEXTERNAL LOADS APPLIED TO JUNCTION -SEE DIAGRAM BELOW/                SK04830
     310X82HRADIAL TEMPERATURE DIFFERENCE -INNER WALL TEMPERATURE MINUS          SK04840
     4OUTER WALL TEMPERATURE/                                                    SK04850
     529X78HAXIAL LOAD -TOTAL TENSILE LOAD ON CYLINDER FROM ALL INFLUENC         SK04860
     6ES EXCEPT PRESSURE/                                                        SK04870
     731X44HPRESSURE -GAGE PRESSURE IN CYLINDERS 2 AND 3/                        SK04880
     831X26HSTRESSES -TENSION POSITIVE//)                                        SK04890
    4 FORMAT (40X36HEXTERNALLY APPLIED LOADS TO JUNCTION//                       SK04900
     159X11H*  POSITIVE/58X15H*** SHEAR FORCE/54X1H*4X1H*/                      SK04910
     253X7H*******/54X6H*    */47X13HPOSITIVE    */                            SK04920
     349X11HMOMENT     */59X1H*/29X61(1H-)/33X17HCYLINDERS 1 AND 2               SK04930
     49X1H*8X10HCYLINDER 3/2(59X1H*/)59X6H*    */59X7H*******/                  SK04940
     559X6H.    */3(59X1H./)29X2H+X9X4HAXIS14X3H0.010X4HAXIS12X2H+X/             SK04950
     629X6(5H- -- )1H.6(5H -- -)/4(59X1H./)59X6H.    */                         SK04960
     759X7H*******/ 43X22HCIRCUMFERENTIAL *    *)                              SK04970
    5 FORMAT(50X10HJUNCTION */55X5HX=0 */59X1H*/                                 SK04980
     129X61(1H-)/59X1H*/47X13HPOSITIVE    */49X11HMOMENT    */                   SK04990
     254X6H*    */53X7H*******/54X6H*    */58X12H*** POSITIVE/                  SK05000
     359X14H*  SHEAR FORCE/10X31HNOTE ARROWS FORMED BY ASTERISKS   )              SK05010
      PRINT 6 IPRCB                                                              SK05020
      PRINT 1                                                                    SK05030
      PRINT 2                                                                    SK05040
      PRINT 3                                                                    SK05050
      PRINT 4                                                                    SK05060
      PRINT 5                                                                    SK05070
      RETURN                                                                     SK05080
      END                                                                        SK05090
```

```
      SUBROUTINE ANSWER (C,D,E,G,X,L,M,N,NN,BM,V)                       SK05100
  140 FORMAT (1H1,51X,15HPROBLEM NUMBER ,I3//45X,28HRESULTS FOR CYLINDER SK05110
     1 NUMBER ,I1)                                                      SK05120
  143 FORMAT (37HO MAXIMUM DISTORTION ENERGY STRESS OF,1PE11.3,31H PSI,  SK05130
     1OCCURS AT  STATION NUMBER,I3,4H, X=,E11.3/27H ON OUTER SURFACE OF SK05140
     2SHELL.)                                                           SK05150
  144 FORMAT (37HO MAXIMUM DISTORTION ENERGY STRESS OF,1PE11.3,31H PSI,  SK05160
     1OCCURS AT  STATION NUMBER,I3,4H, X=,E11.3/27H ON INNER SURFACE OF SK05170
     2SHELL.)                                                           SK05180
  145 FORMAT (//4H STA9X1HX5X12HOUTER STRESS5X12HINNER STRESS5X12HOUTER SK05190
     1STRESS5X12HINNER STRESS34H OUTER DISTORTION INNER DISTORTION/4H  N SK05200
     2010H  LOCATION2(5X12HLONGITUDINAL)2(17H  CIRCUMFERENTIAL)2(4X13HEN SK05210
     3ERGY STRESS))                                                     SK05220
  146 FORMAT (I4,1PE10.3,6E17.3)                                        SK05230
  147 FORMAT (//45X28HRESULTS FOR CYLINDER NUMBER ,I1)                  SK05240
  148 FORMAT(//4H STA9X1HX2(5X12HOUTER STRESS 5X12HINNER STRESS)/       SK05250
     14H  NO10H  LOCATION2(5X12HLONGITUDINAL)2(17H  CIRCUMFERENTIAL)    SK05260
     211X6HMOMENT12X5HSHEAR  )                                          SK05270
      DIMENSION A(201),B(201),C(201),D(201),E(201),G(201),X(201),M(3)   SK05280
     1,BM(201),V(201)                                                   SK05290
      J=2*M(L)+1                                                        SK05300
  139 FORMAT(I20)                                                       SK05310
      DO 1 I=1,J,2                                                      SK05320
      A(I)=(C(I)**2-C(I)*E(I)+E(I)**2)**.5                              SK05330
    1 B(I)=(D(I)**2-D(I)*G(I)+G(I)**2)**.5                              SK05340
      IF (N-2) 2,3,4                                                    SK05350
    2 IF (L-2) 14,15,15                                                 SK05360
   14 PRINT 140 NN,L                                                    SK05370
      GO TO 16                                                          SK05380
   15 PRINT 147 L                                                       SK05390
   16 F=0.                                                              SK05400
      DO 6 I=1,J,2                                                      SK05410
      IF (F-A(I)) 7,8,8                                                 SK05420
    7 F=A(I)                                                            SK05430
      KK=1                                                              SK05440
      K=(I+1)/2                                                         SK05450
    8 IF (F-B(I)) 9,6,6                                                 SK05460
    9 F=B(I)                                                            SK05470
      KK=2                                                              SK05480
      K=(I+1)/2                                                         SK05490
    6 CONTINUE                                                          SK05500
      IF(KK-1)11,11,12                                                  SK05510
   11 KKK=2*K-1                                                         SK05520
      PRINT 143 F,K,X(KKK)                                              SK05530
      GO TO 10                                                          SK05540
   12 KKK=2*K-1                                                         SK05550
      PRINT 144 F,K,X(KKK)                                              SK05560
      GO TO 10                                                          SK05570
    3 PRINT 140 NN,L                                                    SK05580
      PRINT 145                                                         SK05590
```

```
      JJ=J-2                                                                    SK05600
      DO 13 I=1,JJ,2                                                            SK05610
      II=(I+1)/2                                                                SK05620
   13 PRINT 146 II,X(I),C(I),D(I),E(I),G(I),A(I),B(I)                           SK05630
      GO TO 10                                                                  SK05640
    4 PRINT 140 NN,L                                                            SK05650
      PRINT 148                                                                 SK05660
      JJ=J-2                                                                    SK05670
      DO 17 I=1,JJ,2                                                            SK05680
      II=(I+1)/2                                                                SK05690
   17 PRINT 146 II,X(I),C(I),D(I),E(I),G(I),BM(I),V(I)                          SK05700
   10 RETURN                                                                    SK05710
      END                                                                       SK05720
      END                                                                       SK05730
                                                                                SK05740
```

APPENDIX C

Sample Problems

Elementary problems were set up to show the capabilities of the program. No pretense is made that the values used are representative loadings. The problems are described below. No significance should be attached to the numbering system of the problems. A summary of the equivalent stress in each cylinder of each problem is given in Table 1 and sample printouts of problems 20,21,22,80, and 90 along with the input cards for these problems, are given after page C6.

Problem 10 - Three identical cylinders, 16 inches long, 50 inch radius, 0.5 inch wall thickness, Young's Modulus $3X10^7$ psi, Poisson's Ratio 0.3, thermal coefficient of expansion $7.7X10^{-6}$ inches/inch °F, number of increments 25. 100 psig internal pressure in Cylinders 2 and 3; no thermal or mechnical loadings other than pressure. The method of solution used was Option 1 (See Appendix A). Printout option 3.

Problem 20 - Same as problem 10 except Option 2 used for calculation. In cylinder 2, R_1 = 50 inches, R_2 = 50 inches; i.e., hemispherical head. In Cylinder 3, R_1 is infinite, R_2 = 50 inches.

Problem 21 - Same as problem 20 but printout option 2 is

used.

Problem 22 - Same as problem 21 but printout option 1.

Problem 30 - Same as problem 20 with following thermal loading added:

Cylinder 1 Medial wall temperature = $T = 300 - 400(1-e^{-.025x})$ °F.

Cylinders 2 and 3 $T = 300 + 200(1-e^{-.025x})$ °F.

Problem 40 - Same as problem 30 with the following thermal loading added:

Cylinder 1 Axial temperature difference = $\Delta T = 0$ for all x.

Cylinders 2 and 3 $\Delta T = (25)(T_i/T_1)$

where T_i is the median temperature at station i and T_1 is the median temperature at the junction.

Problem 50 - Same as problem 40 with an axial load added;

Cylinder 1 Axial load = $P^* = -5000 - 47.5x$ Lb.

Cylinder 2 $P^* = 3500-47.5x$ Lb.

Cylinder 3 $P^* = -1500+47.5x$ Lb.

Problem 60 - Same as problem 50 but the thickness of Cylinder 3 is progressively reduced.

	Thickness of Cylinder 3
$0.0 \leq x < 2.56$	.5 Inches
$2.56 \leq x < 5.76$	.45 Inches
$5.76 \leq x < 8.96$	.40 Inches
$8.96 \leq x < 12.16$	.35 Inches
$12.16 \leq x \leq 16.0$	.30 Inches

Problem 70 - Same as problem 60 but Cylinder 1 (skirt) is slotted from x = 0 to x = 10 inches.

Problem 80 - Same as problem 70 but externally applied moment and shear are added.

External moment = $M_{oo} = 500 \frac{in\text{-}lb}{in}$

External shear = $V_{oo} = 500 \frac{lb}{in}$

Problem 90 - Same as problem 20 but length of cylinder 1 is reduced to 10^{-7} inches, effectively eliminating it from the problem.

TABLE I

Maximum Equivalent Stresses in Sample Problems

Loc. is the distance from the junction, in inches, of the maximum equivalent stress. If preceded by an I, the maximum stress was on the inner surface of the cylinder, if by an O, the maximum stress was on the outer surface.

Problem Number	Cylinder 1 Maximum Stress	Loc.	Cylinder 2 Maximum Stress	Loc.	Cylinder 3 Maximum Stress	Loc.
10	9,672	I-0.00	11,800	I-0.00	8,878	O-7.68
20	5,437	I-0.00	8,142	I-0.00	9,019	O-7.68
30	13,480	I-0.00	18,100	I-0.00	9,083	O-7.68
40	13,780	I-0.00	13,470	O-12.8	16,870	O-16.0
50	13,810	I-0.00	13,480	O-12.8	16,870	O-16.0
60	13,920	I-0.00	13,600	O-12.8	24,230	O-16.0
70	9,806	I-0.00	11,340	O-12.16	23,600	O-16.0
80	13,700	I-0.00	15,920	O-0.00	27,400	O-16.0
90	6,000	O-0.00	6,614	I-0.00	8,932	O-7.04

Discussion of Results

Since the sample problems are somewhat complex and are used mainly to display the capabilities of the program, the purpose of the following discussion is mainly to point out those results which the writer felt most interesting and to offer what seem to be plausible explanations of these results.

Problems 20 and 90 have no loadings but pressure and differ only in that 20 has a skirt and 90 does not. In comparing the stresses in Table 1 of Cylinders 2 and 3, it will be noted that the addition of the skirt did not grossly affect the stresses or their locations. The stresses did increase somewhat due to the moment exerted by the skirt upon the junction, but this increase was partially balanced by the skirt's constraint on the outward movement of the junction. This may be seen by comparing the circumferential stresses of Cylinders 2 and 3 of the two problems. The results for Cylinder 1 of problem 90, should be neglected.

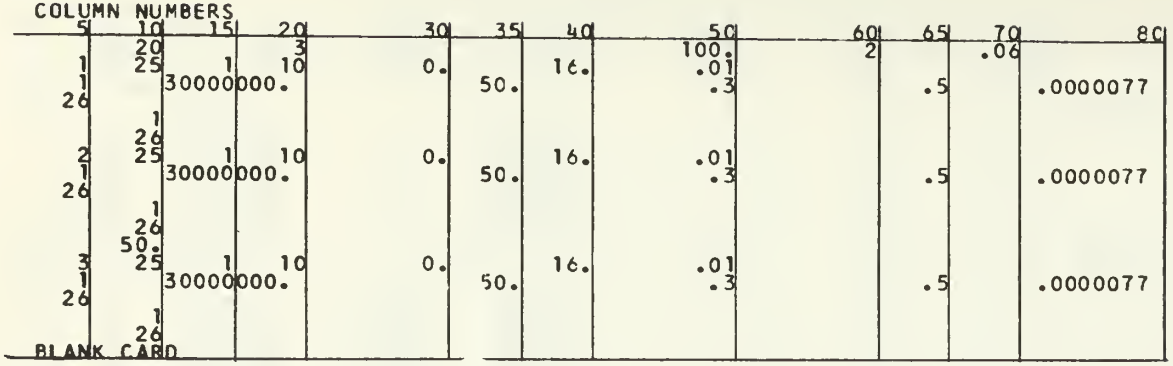
Note that the application of an external moment and shear on problem 80 considerably changes the equivalent stress at the remote end of Cylinder 3 from what it was in problem 70. Since the length of the cylinder was supposedly chosen such that a force applied at the junction should not

affect the remote end, this change in stress might be puzzling. However the junction end moment in Cylinder 3 of problem 70 was -88 in-lb. and in problem 80 was -559 in-lb., an increase of over 500%. Also the junction end shear increases from 59 lb/in to 471 lb/in, an increase of about 700%. Since, due to the sign conventions for Cylinder 3, (See Figure 5 of text) a moment and shear of opposite signs have a cumulative effect on the moment, this 14 percent change in stress at the end is not unreasonable.

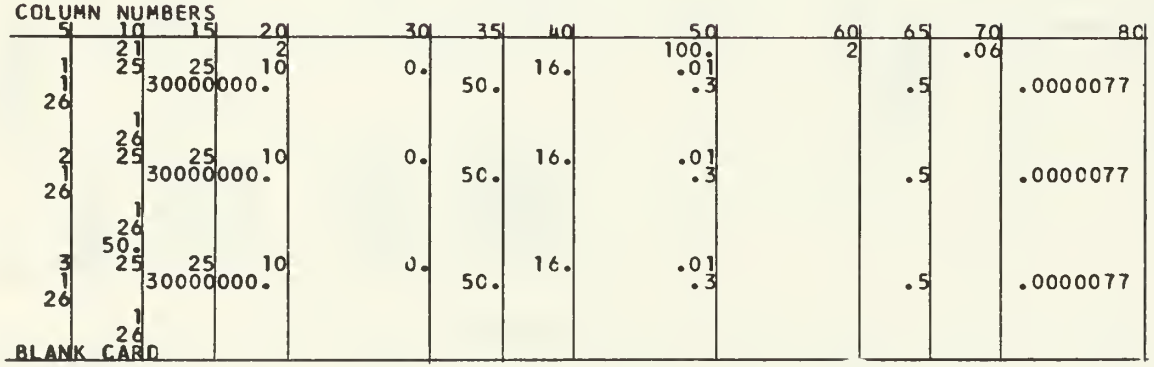
From the printout of problem 80 it will be noted that at station 25 of Cylinder 3 the stresses seem to change radically from those of the previous station. The probable reason for this is that in this particular cylinder a large nonlinearity is imposed upon the whole length of the cylinder by the decrease in wall thickness. Such a nonlinearity will create internal moments and shears in the wall. However we are still forcing the shear and curvature to be zero at the end (Station 26) and therefore a large compensation occurs near the end. For accurate results near this point, a longer cylinder must be used with more intervals.

DATA CAROS

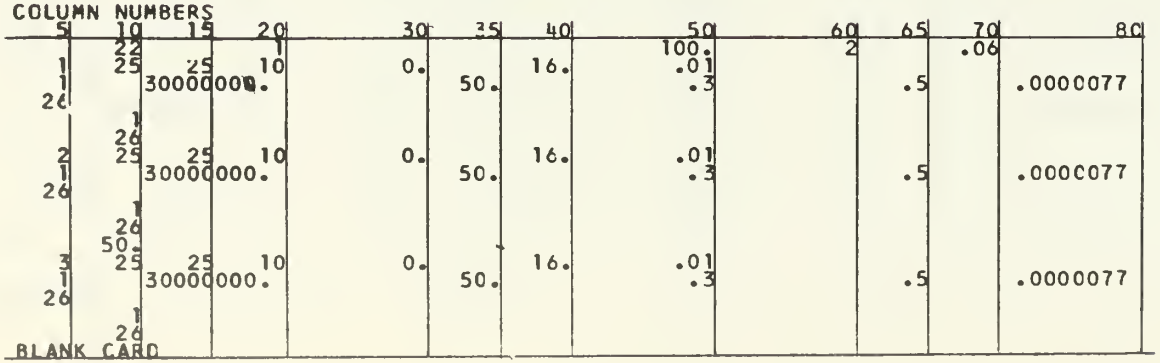
PROBLEM 20



PROBLEM 21



PROBLEM 22



DATA CARDS

PROBLEM 80

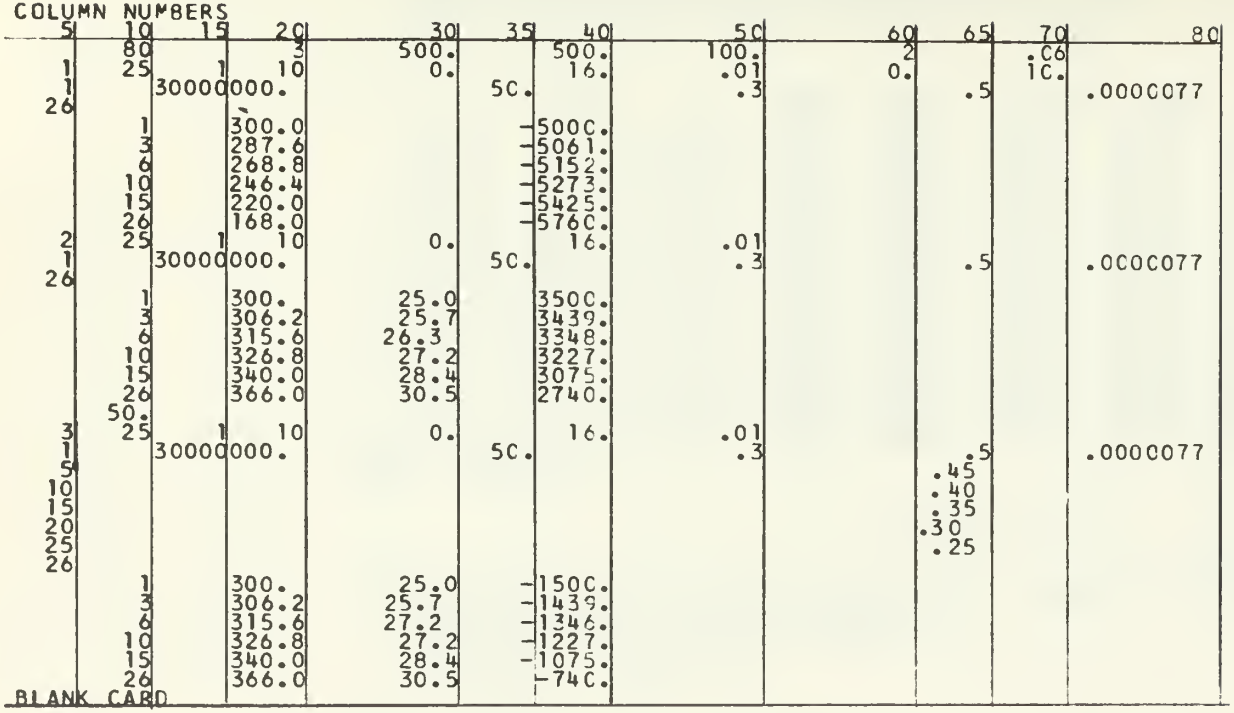
```
COLUMN NUMBERS
   5   10   15   20        30   35   40        50        60   65   70        80
       80        3       500.       500.      100.         2       .06
   1   25    1   10        0.        16.       .01        0.       10.
   1       30000000.              50.          .3                .5       .0000077
  26
        1       300.0                  -5000.
        3       287.6                  -5061.
        6       268.8                  -5152.
       10       246.4                  -5273.
       15       220.0                  -5425.
       26       168.0                  -5760.
   2   25    1   10        0.        16.       .01
   1       30000000.              50.          .3                .5       .0000077
  26
        1       300.      25.0       3500.
        3       306.2     25.7       3439.
        6       315.6    26.3        3348.
       10       326.8     27.2       3227.
       15       340.0     28.4       3075.
       26       366.0     30.5       2740.
      50.
   3   25    1   10        0.        16.       .01
   1       30000000.              50.          .3                .5       .0000077
   5                                                                .45
  10                                                                .40
  15                                                                .35
  20                                                               .30
  25                                                                .25
  26
        1       300.      25.0       -1500.
        3       306.2    25.7        -1439.
        6       315.6    27.2        -1346.
       10       326.8     27.2       -1227.
       15       340.0     28.4       -1075.
       26       366.0     30.5        -740.
BLANK CARD
```

PROBLEM 90

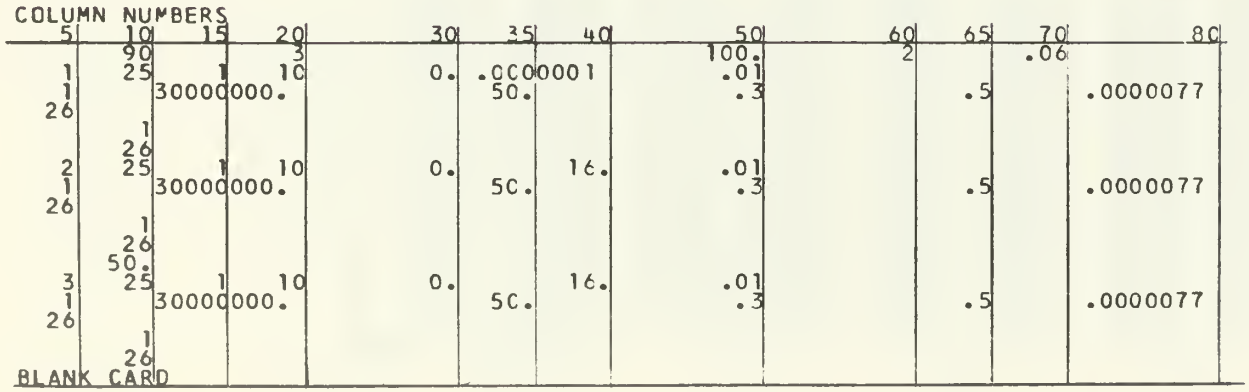
```
COLUMN NUMBERS
   5   10   15   20        30   35   40        50        60   65   70        80
       90        3                                100.         2       .06
   1   25    1   10        0.  .0000001          .01
   1       30000000.              50.          .3                .5       .0000077
  26
        1
       26
   2   25    1   10        0.        16.       .01
   1       30000000.              50.          .3                .5       .0000077
  26
        1
       26
      50.
   3   25    1   10        0.        16.       .01
   1       30000000.              50.          .3                .5       .0000077
  26
        1
       26
BLANK CARD
```

DATA CARDS

PROBLEM 80

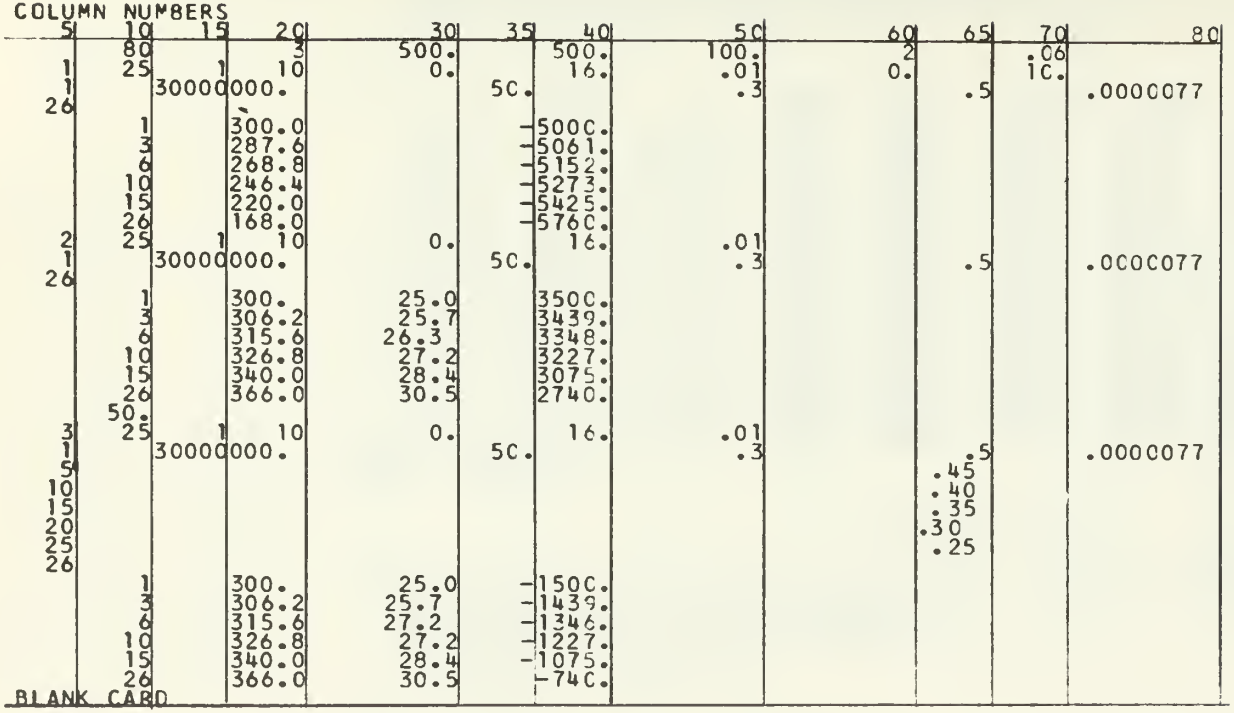


PROBLEM 90

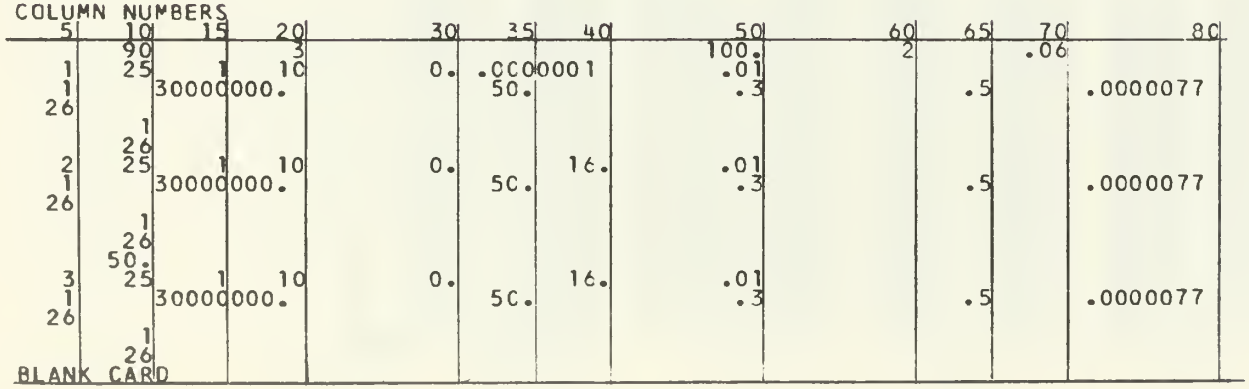


DATA CARDS

PROBLEM 80



PROBLEM 90



HOT SKIRT PROBLEM NUMBER 20
CYLINDER NUMBER 1

INPUT DATA

NUMBER OF INCREMENTS 25 MINIMUM X .000E-01 INCHES MAXIMUM X 1.600E+01 INCHES
MOMENT APPLIED TO JUNCTION .000E-01 INCH POUNDS
SHEAR LOAD APPLIED TO JUNCTION .000E-01 POUNDS
CYLINDER SLOTTED FROM X= .000E-01 TO X= .000E-01
FRACTION OF MAXIMUM DISTORTION USED AS CONVERGENCE CRITERION 1.00E-02
EXPONENT 10
MINIMUM CONVERGENCE FRACTION 6.00E-02

CYLINDER PARAMETERS

STA NO	X LOCATION	YOUNGS MODULUS	RADIUS	POISSONS RATIO	WALL THICKNESS	THERMAL COEFF	MEDIAN TEMP	RADIAL TEMP DIFF	AXIAL LOAD
1	.000E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
2	6.400E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
3	1.280E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
4	1.920E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
5	2.560E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
6	3.200E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
7	3.840E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
8	4.480E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
9	5.120E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
10	5.760E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
11	6.400E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
12	7.040E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
13	7.680E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
14	8.320E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
15	8.960E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
16	9.600E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
17	1.024E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
18	1.088E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
19	1.152E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
20	1.216E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
21	1.280E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
22	1.344E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
23	1.408E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
24	1.472E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
25	1.536E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
26	1.600E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01

NUMBER OF ITERATIONS 1
NUMBER OF ITERATIONS 23
NUMBER OF ITERATIONS 23

HOT SKIRT PROBLEM NUMBER 20
CYLINDER NUMBER 2

INPUT DATA

NUMBER OF INCREMENTS 25 MINIMUM X .000E-01 INCHES MAXIMUM X 1.600E+01 INCHES
MOMENT APPLIED TO JUNCTION .000E-01 INCH POUNDS
SHEAR LOAD APPLIED TO JUNCTION .000E-01 POUNDS
CYLINDER SLOTTED FROM X= .000E-01 TO X= .000E-01
FRACTION OF MAXIMUM DISTORTION USED AS CONVERGENCE CRITERION 1.00E-02
EXPONENT 10
MINIMUM CONVERGENCE FRACTION 6.00E-02
R1= 5.000E+01, R2= 5.000E+01

CYLINDER PARAMETERS

STA NO	X LOCATION	YOUNGS MODULUS	RADIUS	POISSONS RATIO	WALL THICKNESS	THERMAL COEFF	MEDIAN TEMP	RADIAL TEMP DIFF	AXIAL LOAD
1	.000E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
2	6.400E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
3	1.280E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
4	1.920E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
5	2.560E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
6	3.200E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
7	3.840E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
8	4.480E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
9	5.120E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
10	5.760E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
11	6.400E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
12	7.040E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
13	7.680E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
14	8.320E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
15	8.960E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
16	9.600E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
17	1.024E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
18	1.088E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
19	1.152E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
20	1.216E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
21	1.280E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
22	1.344E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
23	1.408E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
24	1.472E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
25	1.536E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
26	1.600E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01

NUMBER OF ITERATIONS 1
NUMBER OF ITERATIONS 23
NUMBER OF ITERATIONS 23

HOT SKIRT PROBLEM NUMBER 20
CYLINDER NUMBER 3

INPUT DATA**********

NUMBER OF INCREMENTS 25 MINIMUM X .000E-01 INCHES MAXIMUM X 1.600E+01 INCHES
MOMENT APPLIED TO JUNCTION .000E-01 INCH POUNDS
SHEAR LOAD APPLIED TO JUNCTION .000E-01 POUNDS
CYLINDER SLOTTED FROM X= .000E-01 TO X= .000E-01
FRACTION OF MAXIMUM DISTORTION USED AS CONVERGENCE CRITERION 1.00E-02
EXPONENT 10
MINIMUM CONVERGENCE FRACTION 6.00E-02
R1 IS INFINITE, R2= 5.000E+01

CYLINDER PARAMETERS

STA NO	X LOCATION	YOUNGS MODULUS	RADIUS	POISSONS RATIO	WALL THICKNESS	THERMAL COEFF	MEDIAN TEMP	RADIAL TEMP DIFF	AXIAL LOAD
1	.000E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
2	6.400E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
3	1.280E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
4	1.920E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
5	2.560E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
6	3.200E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
7	3.840E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
8	4.480E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
9	5.120E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
10	5.760E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
11	6.400E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
12	7.040E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
13	7.680E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
14	8.320E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
15	8.960E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
16	9.600E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
17	1.024E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
18	1.088E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
19	1.152E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
20	1.216E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
21	1.280E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
22	1.344E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
23	1.408E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
24	1.472E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
25	1.536E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
26	1.600E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01

NUMBER OF ITERATIONS 1
NUMBER OF ITERATIONS 23
NUMBER OF ITERATIONS 23

PROBLEM NUMBER 20

RESULTS FOR CYLINDER NUMBER 1

STA NO	X LOCATION	OUTER STRESS LONGITUDINAL	INNER STRESS LONGITUDINAL	OUTER STRESS CIRCUMFERENTIAL	INNER STRESS CIRCUMFERENTIAL	MOMENT	SHEAR
1	.000E-01	2.415E+03	-2.415E+03	5.250E+03	3.800E+03	-1.006E+02	1.136E+02
2	6.400E-01	8.860E+02	-8.860E+02	4.242E+03	3.710E+03	-3.692E+01	8.685E+01
3	1.280E+00	-2.530E+02	2.530E+02	3.324E+03	3.476E+03	1.054E+01	6.332E+01
4	1.920E+00	-1.059E+03	1.059E+03	2.514E+03	3.150E+03	4.413E+01	4.349E+01
5	2.560E+00	-1.589E+03	1.589E+03	1.819E+03	2.772E+03	6.621E+01	2.723E+01
6	3.200E+00	-1.896E+03	1.896E+03	1.238E+03	2.375E+03	7.899E+01	1.429E+01
7	3.840E+00	-2.028E+03	2.028E+03	7.654E+02	1.982E+03	8.450E+01	4.330E+00
8	4.480E+00	-2.029E+03	2.029E+03	3.930E+02	1.610E+03	8.453E+01	-3.025E+00
9	5.120E+00	-1.935E+03	1.935E+03	1.095E+02	1.271E+03	8.063E+01	-8.165E+00
10	5.760E+00	-1.778E+03	1.778E+03	-9.727E+01	9.695E+02	7.408E+01	-1.147E+01
11	6.400E+00	-1.583E+03	1.583E+03	-2.396E+02	7.100E+02	6.594E+01	-1.330E+01
12	7.040E+00	-1.369E+03	1.369E+03	-3.293E+02	4.923E+02	5.705E+01	-1.398E+01
13	7.680E+00	-1.153E+03	1.153E+03	-3.774E+02	3.145E+02	4.805E+01	-1.380E+01
14	8.320E+00	-9.455E+02	9.455E+02	-3.935E+02	1.737E+02	3.939E+01	-1.299E+01
15	8.960E+00	-7.540E+02	7.540E+02	-3.864E+02	6.597E+01	3.142E+01	-1.178E+01
16	9.600E+00	-5.836E+02	5.836E+02	-3.631E+02	-1.298E+01	2.432E+01	-1.032E+01
17	1.024E+01	-4.369E+02	4.369E+02	-3.296E+02	-6.741E+01	1.820E+01	-8.752E+00
18	1.088E+01	-3.147E+02	3.147E+02	-2.903E+02	-1.015E+02	1.311E+01	-7.177E+00
19	1.152E+01	-2.164E+02	2.164E+02	-2.488E+02	-1.190E+02	9.018E+00	-5.672E+00
20	1.216E+01	-1.405E+02	1.405E+02	-2.076E+02	-1.233E+02	5.853E+00	-4.294E+00
21	1.280E+01	-8.452E+01	8.452E+01	-1.682E+02	-1.175E+02	3.522E+00	-3.081E+00
22	1.344E+01	-4.582E+01	4.582E+01	-1.314E+02	-1.039E+02	1.909E+00	-2.059E+00
23	1.408E+01	-2.128E+01	2.128E+01	-9.755E+01	-8.478E+01	8.869E-01	-1.241E+00
24	1.472E+01	-7.690E+00	7.690E+00	-6.632E+01	-6.170E+01	3.204E-01	-6.371E-01
25	1.536E+01	-1.712E+00	1.712E+00	-3.715E+01	-3.612E+01	7.135E-02	-2.503E-01

PROBLEM NUMBER 20

RESULTS FOR CYLINDER NUMBER 2

STA NO	X LOCATION	OUTER STRESS LONGITUDINAL	INNER STRESS LONGITUDINAL	OUTER STRESS CIRCUMFERENTIAL	INNER STRESS CIRCUMFERENTIAL	MOMENT	SHEAR
1	.000E-01	1.154E+03	8.846E+03	4.871E+03	7.179E+03	1.603E+02	-2.118E+01
2	6.400E-01	1.524E+03	8.476E+03	4.519E+03	6.605E+03	1.448E+02	-2.590E+01
3	1.280E+00	1.949E+03	8.051E+03	4.288E+03	6.118E+03	1.271E+02	-2.837E+01
4	1.920E+00	2.395E+03	7.605E+03	4.153E+03	5.716E+03	1.085E+02	-2.885E+01
5	2.560E+00	2.836E+03	7.164E+03	4.094E+03	5.393E+03	9.018E+01	-2.787E+01
6	3.200E+00	3.251E+03	6.749E+03	4.093E+03	5.142E+03	7.286E+01	-2.587E+01
7	3.840E+00	3.630E+03	6.370E+03	4.133E+03	4.955E+03	5.706E+01	-2.324E+01
8	4.480E+00	3.965E+03	6.035E+03	4.200E+03	4.821E+03	4.311E+01	-2.026E+01
9	5.120E+00	4.253E+03	5.747E+03	4.284E+03	4.732E+03	3.113E+01	-1.717E+01
10	5.760E+00	4.493E+03	5.507E+03	4.376E+03	4.680E+03	2.113E+01	-1.414E+01
11	6.400E+00	4.687E+03	5.313E+03	4.470E+03	4.657E+03	1.303E+01	-1.128E+01
12	7.040E+00	4.840E+03	5.160E+03	4.560E+03	4.656E+03	6.686E+00	-8.685E+00
13	7.680E+00	4.954E+03	5.046E+03	4.643E+03	4.671E+03	1.913E+00	-6.390E+00
14	8.320E+00	5.036E+03	4.964E+03	4.718E+03	4.697E+03	-1.493E+00	-4.416E+00
15	8.960E+00	5.090E+03	4.910E+03	4.784E+03	4.730E+03	-3.739E+00	-2.764E+00
16	9.600E+00	5.121E+03	4.879E+03	4.840E+03	4.768E+03	-5.031E+00	-1.422E+00
17	1.024E+01	5.133E+03	4.867E+03	4.887E+03	4.807E+03	-5.560E+00	-3.689E-01
18	1.088E+01	5.132E+03	4.868E+03	4.926E+03	4.847E+03	-5.503E+00	4.221E-01
19	1.152E+01	5.120E+03	4.880E+03	4.958E+03	4.886E+03	-5.020E+00	9.774E-01
20	1.216E+01	5.102E+03	4.898E+03	4.984E+03	4.923E+03	-4.252E+00	1.323E+00
21	1.280E+01	5.080E+03	4.920E+03	5.006E+03	4.958E+03	-3.327E+00	1.480E+00
22	1.344E+01	5.057E+03	4.943E+03	5.026E+03	4.992E+03	-2.357E+00	1.469E+00
23	1.408E+01	5.035E+03	4.965E+03	5.044E+03	5.023E+03	-1.447E+00	1.303E+00
24	1.472E+01	5.017E+03	4.983E+03	5.062E+03	5.052E+03	-6.897E-01	9.911E-01
25	1.536E+01	5.004E+03	4.996E+03	5.081E+03	5.079E+03	-1.779E-01	5.388E-01

PROBLEM NUMBER 20

RESULTS FOR CYLINDER NUMBER 3

STA NO	X LOCATION	OUTER STRESS LONGITUDINAL	INNER STRESS LONGITUDINAL	OUTER STRESS CIRCUMFERENTIAL	INNER STRESS CIRCUMFERENTIAL	MOMENT	SHEAR
1	.000E-01	3.569E+03	6.431E+03	5.596E+03	6.454E+03	5.963E+01	-9.241E+01
2	6.400E-01	4.799E+03	5.201E+03	6.500E+03	6.621E+03	8.355E+00	-6.914E+01
3	1.280E+00	5.693E+03	4.307E+03	7.310E+03	6.894E+03	-2.886E+01	-4.891E+01
4	1.920E+00	6.302E+03	3.698E+03	8.014E+03	7.233E+03	-5.425E+01	-3.212E+01
5	2.560E+00	6.679E+03	3.321E+03	8.609E+03	7.602E+03	-6.998E+01	-1.857E+01
6	3.200E+00	6.873E+03	3.127E+03	9.099E+03	7.976E+03	-7.803E+01	-7.978E+00
7	3.840E+00	6.925E+03	3.075E+03	9.491E+03	8.336E+03	-8.019E+01	2.236E-03
8	4.480E+00	6.873E+03	3.127E+03	9.794E+03	8.671E+03	-7.802E+01	5.734E+00
9	5.120E+00	6.748E+03	3.252E+03	1.002E+04	8.971E+03	-7.285E+01	9.580E+00
10	5.760E+00	6.578E+03	3.422E+03	1.018E+04	9.233E+03	-6.576E+01	1.189E+01
11	6.400E+00	6.383E+03	3.617E+03	1.029E+04	9.455E+03	-5.763E+01	1.298E+01
12	7.040E+00	6.179E+03	3.821E+03	1.035E+04	9.639E+03	-4.914E+01	1.315E+01
13	7.680E+00	5.979E+03	4.021E+03	1.037E+04	9.787E+03	-4.080E+01	1.263E+01
14	8.320E+00	5.791E+03	4.209E+03	1.038E+04	9.901E+03	-3.297E+01	1.165E+01
15	8.960E+00	5.621E+03	4.379E+03	1.036E+04	9.987E+03	-2.589E+01	1.036E+01
16	9.600E+00	5.473E+03	4.527E+03	1.033E+04	1.005E+04	-1.970E+01	8.923E+00
17	1.024E+01	5.347E+03	4.653E+03	1.030E+04	1.009E+04	-1.447E+01	7.435E+00
18	1.088E+01	5.245E+03	4.755E+03	1.026E+04	1.011E+04	-1.019E+01	5.983E+00
19	1.152E+01	5.163E+03	4.837E+03	1.022E+04	1.012E+04	-6.812E+00	4.627E+00
20	1.216E+01	5.102E+03	4.898E+03	1.018E+04	1.012E+04	-4.265E+00	3.412E+00
21	1.280E+01	5.059E+03	4.941E+03	1.014E+04	1.011E+04	-2.446E+00	2.365E+00
22	1.344E+01	5.030E+03	4.970E+03	1.011E+04	1.009E+04	-1.239E+00	1.504E+00
23	1.408E+01	5.012E+03	4.988E+03	1.008E+04	1.007E+04	-5.202E-01	8.414E-01
24	1.472E+01	5.004E+03	4.996E+03	1.005E+04	1.004E+04	-1.617E-01	3.813E-01
25	1.536E+01	5.001E+03	4.999E+03	1.002E+04	1.002E+04	-3.218E-02	1.263E-01

HOT SKIRT PROBLEM NUMBER 21
CYLINDER NUMBER 1

INPUT DATA**********

NUMBER OF INCREMENTS 25 MINIMUM X .000E-01 INCHES MAXIMUM X 1.600E+01 INCHES
MOMENT APPLIED TO JUNCTION .000E-01 INCH POUNDS
SHEAR LOAD APPLIED TO JUNCTION .000E-01 POUNDS
CYLINDER SLOTTED FROM X= .000E-01 TO X= .000E-01
FRACTION OF MAXIMUM DISTORTION USED AS CONVERGENCE CRITERION 1.00E-02
EXPONENT 10
MINIMUM CONVERGENCE FRACTION 6.00E-02

CYLINDER PARAMETERS

STA NO	X LOCATION	YOUNGS MODULUS	RADIUS	POISSONS RATIO	WALL THICKNESS	THERMAL COEFF	MEDIAN TEMP	RADIAL TEMP DIFF	AXIAL LOAD
1	.000E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
26	1.600E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01

NUMBER OF ITERATIONS 1
NUMBER OF ITERATIONS 23
NUMBER OF ITERATIONS 23

HOT SKIRT PROBLEM NUMBER 21
CYLINDER NUMBER 2

INPUT DATA**********

NUMBER OF INCREMENTS 25 MINIMUM X .000E-01 INCHES MAXIMUM X 1.600E+01 INCHES
MOMENT APPLIED TO JUNCTION .000E-01 INCH POUNDS
SHEAR LOAD APPLIED TO JUNCTION .000E-01 POUNDS
CYLINDER SLOTTED FROM X= .000E-01 TO X= .000E-01
FRACTION OF MAXIMUM DISTORTION USED AS CONVERGENCE CRITERION 1.00E-02
EXPONENT 10
MINIMUM CONVERGENCE FRACTION 6.00E-02
R1= 5.000E+01, R2= 5.00CE+01

CYLINDER PARAMETERS

STA NO	X LOCATION	YOUNGS MODULUS	RADIUS	POISSONS RATIO	WALL THICKNESS	THERMAL COEFF	MEDIAN TEMP	RADIAL TEMP DIFF	AXIAL LOAD
1	.000E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
26	1.600E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01

NUMBER OF ITERATIONS 1
NUMBER OF ITERATIONS 23
NUMBER OF ITERATIONS 23

HOT SKIRT PROBLEM NUMBER 21
CYLINDER NUMBER 3

INPUT DATA**********

NUMBER OF INCREMENTS 25 MINIMUM X .000E-01 INCHES MAXIMUM X 1.600E+01 INCHES
MOMENT APPLIED TO JUNCTION .000E-01 INCH POUNDS
SHEAR LOAD APPLIED TO JUNCTION .000E-01 POUNDS
CYLINDER SLOTTED FROM X= .000E-01 TO X= .000E-01
FRACTION OF MAXIMUM DISTORTION USED AS CONVERGENCE CRITERION 1.00E-02
EXPONENT 10
MINIMUM CONVERGENCE FRACTION 6.00E-02
R1 IS INFINITE, R2= 5.00E+01

CYLINDER PARAMETERS

STA NO	X LOCATION	YOUNGS MODULUS	RADIUS	POISSONS RATIO	WALL THICKNESS	THERMAL COEFF	MEDIAN TEMP	RADIAL TEMP DIFF	AXIAL LOAD
1	.000E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
26	1.600E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01

NUMBER OF ITERATIONS 1
NUMBER OF ITERATIONS 23
NUMBER OF ITERATIONS 23

PROBLEM NUMBER 21

RESULTS FOR CYLINDER NUMBER 1

STA NO	X LOCATION	OUTER STRESS LONGINUDINAL	INNER STRESS LONGINUDINAL	OUTER STRESS CIRCUMFERENTIAL	INNER STRESS CIRCUMFERENTIAL	OUTER DISTORTION ENERGY STRESS	INNER DISTORTION ENERGY STRESS
1	.000E-01	2.415E+03	-2.415E+03	5.250E+03	3.800E+03	4.551E+03	5.427E+03
2	6.400E-01	8.860E+02	-8.860E+02	4.242E+03	3.710E+03	3.875E+03	4.223E+03
3	1.280E+00	-2.530E+02	2.530E+02	3.324E+03	3.476E+03	3.458E+03	3.357E+03
4	1.920E+00	-1.059E+03	1.059E+03	2.514E+03	3.150E+03	3.179E+03	2.776E+03
5	2.560E+00	-1.589E+03	1.589E+03	1.819E+03	2.772E+03	2.954E+03	2.409E+03
6	3.200E+00	-1.896E+03	1.896E+03	1.238E+03	2.375E+03	2.733E+03	2.175E+03
7	3.840E+00	-2.028E+03	2.028E+03	7.654E+02	1.982E+03	2.500E+03	2.005E+03
8	4.480E+00	-2.029E+03	2.029E+03	3.930E+02	1.610E+03	2.251E+03	1.855E+03
9	5.120E+00	-1.935E+03	1.935E+03	1.095E+02	1.271E+03	1.992E+03	1.703E+03
10	5.760E+00	-1.778E+03	1.778E+03	-9.727E+01	9.695E+02	1.731E+03	1.542E+03
11	6.400E+00	-1.583E+03	1.583E+03	-2.396E+02	7.100E+02	1.478E+03	1.373E+03
12	7.040E+00	-1.369E+03	1.369E+03	-3.293E+02	4.923E+02	1.238E+03	1.201E+03
13	7.680E+00	-1.153E+03	1.153E+03	-3.774E+02	3.145E+02	1.018E+03	1.032E+03
14	8.320E+00	-9.455E+02	9.455E+02	-3.935E+02	1.737E+02	8.226E+02	8.717E+02
15	8.960E+00	-7.540E+02	7.540E+02	-3.864E+02	6.597E+01	6.530E+02	7.232E+02
16	9.600E+00	-5.836E+02	5.836E+02	-3.631E+02	-1.298E+01	5.104E+02	5.902E+02
17	1.024E+01	-4.369E+02	4.369E+02	-3.296E+02	-6.741E+01	3.943E+02	4.742E+02
18	1.088E+01	-3.147E+02	3.147E+02	-2.903E+02	-1.015E+02	3.032E+02	3.759E+02
19	1.152E+01	-2.164E+02	2.164E+02	-2.488E+02	-1.190E+02	2.343E+02	2.945E+02
20	1.216E+01	-1.405E+02	1.405E+02	-2.076E+02	-1.233E+02	1.835E+02	2.286E+02
21	1.280E+01	-8.452E+01	8.452E+01	-1.682E+02	-1.175E+02	1.457E+02	1.757E+02
22	1.344E+01	-4.582E+01	4.582E+01	-1.314E+02	-1.039E+02	1.155E+02	1.329E+02
23	1.408E+01	-2.128E+01	2.128E+01	-9.755E+01	-8.478E+01	8.884E+01	9.718E+01
24	1.472E+01	-7.690E+00	7.690E+00	-6.632E+01	-6.170E+01	6.283E+01	6.589E+01
25	1.536E+01	-1.712E+00	1.712E+00	-3.715E+01	-3.612E+01	3.632E+01	3.700E+01

PROBLEM NUMBER 21

RESULTS FOR CYLINDER NUMBER 2

STA NO	X LOCATION	OUTER STRESS LONGITUDINAL	INNER STRESS LONGITUDINAL	OUTER STRESS CIRCUMFERENTIAL	INNER STRESS CIRCUMFERENTIAL	OUTER DISTORTION ENERGY STRESS	INNER DISTORTION ENERGY STRESS
1	.000E-01	1.154E+03	8.846E+03	4.871E+03	7.179E+03	4.409E+03	8.142E+03
2	6.400E-01	1.524E+03	8.476E+03	4.519E+03	6.605E+03	3.982E+03	7.713E+03
3	1.280E+00	1.949E+03	8.051E+03	4.288E+03	6.118E+03	3.718E+03	7.279E+03
4	1.920E+00	2.395E+03	7.605E+03	4.153E+03	5.716E+03	3.611E+03	6.858E+03
5	2.560E+00	2.836E+03	7.164E+03	4.094E+03	5.393E+03	3.633E+03	6.463E+03
6	3.200E+00	3.251E+03	6.749E+03	4.093E+03	5.142E+03	3.744E+03	6.106E+03
7	3.840E+00	3.630E+03	6.370E+03	4.133E+03	4.955E+03	3.906E+03	5.793E+03
8	4.480E+00	3.965E+03	6.035E+03	4.200E+03	4.821E+03	4.088E+03	5.529E+03
9	5.120E+00	4.253E+03	5.747E+03	4.284E+03	4.732E+03	4.269E+03	5.313E+03
10	5.760E+00	4.493E+03	5.507E+03	4.376E+03	4.680E+03	4.436E+03	5.144E+03
11	6.400E+00	4.687E+03	5.313E+03	4.470E+03	4.657E+03	4.582E+03	5.017E+03
12	7.040E+00	4.840E+03	5.160E+03	4.560E+03	4.656E+03	4.706E+03	4.928E+03
13	7.680E+00	4.954E+03	5.046E+03	4.643E+03	4.671E+03	4.806E+03	4.869E+03
14	8.320E+00	5.036E+03	4.964E+03	4.718E+03	4.697E+03	4.885E+03	4.836E+03
15	8.960E+00	5.090E+03	4.910E+03	4.784E+03	4.730E+03	4.944E+03	4.823E+03
16	9.600E+00	5.121E+03	4.879E+03	4.840E+03	4.768E+03	4.986E+03	4.825E+03
17	1.024E+01	5.133E+03	4.867E+03	4.887E+03	4.807E+03	5.015E+03	4.837E+03
18	1.088E+01	5.132E+03	4.868E+03	4.926E+03	4.847E+03	5.032E+03	4.857E+03
19	1.152E+01	5.120E+03	4.880E+03	4.958E+03	4.886E+03	5.041E+03	4.883E+03
20	1.216E+01	5.102E+03	4.898E+03	4.984E+03	4.923E+03	5.044E+03	4.911E+03
21	1.280E+01	5.080E+03	4.920E+03	5.006E+03	4.958E+03	5.044E+03	4.939E+03
22	1.344E+01	5.057E+03	4.943E+03	5.026E+03	4.992E+03	5.041E+03	4.966E+03
23	1.408E+01	5.035E+03	4.965E+03	5.044E+03	5.023E+03	5.039E+03	4.994E+03
24	1.472E+01	5.017E+03	4.983E+03	5.062E+03	5.052E+03	5.039E+03	5.018E+03
25	1.536E+01	5.004E+03	4.996E+03	5.081E+03	5.079E+03	5.043E+03	5.038E+03

PROBLEM NUMBER 21

RESULTS FOR CYLINDER NUMBER 3

STA NO	X LOCATION	OUTER STRESS LONGITUDINAL	INNER STRESS LONGITUDINAL	OUTER STRESS CIRCUMFERENTIAL	INNER STRESS CIRCUMFERENTIAL	OUTER DISTORTION ENERGY STRESS	INNER DISTORTION ENERGY STRESS
1	.000E-01	3.569E+03	6.431E+03	5.596E+03	6.454E+03	4.907E+03	6.443E+03
2	6.400E-01	4.799E+03	5.201E+03	6.500E+03	6.621E+03	5.839E+03	6.037E+03
3	1.280E+00	5.693E+03	4.307E+03	7.310E+03	6.894E+03	6.651E+03	6.032E+03
4	1.920E+00	6.302E+03	3.698E+03	8.014E+03	7.233E+03	7.310E+03	6.264E+03
5	2.560E+00	6.679E+03	3.321E+03	8.609E+03	7.602E+03	7.825E+03	6.601E+03
6	3.200E+00	6.873E+03	3.127E+03	9.099E+03	7.976E+03	8.215E+03	6.961E+03
7	3.840E+00	6.925E+03	3.075E+03	9.491E+03	8.336E+03	8.503E+03	7.302E+03
8	4.480E+00	6.873E+03	3.127E+03	9.794E+03	8.671E+03	8.709E+03	7.606E+03
9	5.120E+00	6.748E+03	3.252E+03	1.002E+04	8.971E+03	8.850E+03	7.867E+03
10	5.760E+00	6.578E+03	3.422E+03	1.018E+04	9.233E+03	8.941E+03	8.085E+03
11	6.400E+00	6.383E+03	3.617E+03	1.029E+04	9.455E+03	8.993E+03	8.264E+03
12	7.040E+00	6.179E+03	3.821E+03	1.035E+04	9.639E+03	9.017E+03	8.407E+03
13	7.680E+00	5.979E+03	4.021E+03	1.037E+04	9.787E+03	9.019E+03	8.520E+03
14	8.320E+00	5.791E+03	4.209E+03	1.038E+04	9.901E+03	9.006E+03	8.607E+03
15	8.960E+00	5.621E+03	4.379E+03	1.036E+04	9.987E+03	8.983E+03	8.671E+03
16	9.600E+00	5.473E+03	4.527E+03	1.033E+04	1.005E+04	8.952E+03	8.715E+03
17	1.024E+01	5.347E+03	4.653E+03	1.030E+04	1.009E+04	8.918E+03	8.744E+03
18	1.088E+01	5.245E+03	4.755E+03	1.026E+04	1.011E+04	8.883E+03	8.760E+03
19	1.152E+01	5.163E+03	4.837E+03	1.022E+04	1.012E+04	8.848E+03	8.765E+03
20	1.216E+01	5.102E+03	4.898E+03	1.018E+04	1.012E+04	8.814E+03	8.762E+03
21	1.280E+01	5.059E+03	4.941E+03	1.014E+04	1.011E+04	8.782E+03	8.752E+03
22	1.344E+01	5.030E+03	4.970E+03	1.011E+04	1.009E+04	8.753E+03	8.738E+03
23	1.408E+01	5.012E+03	4.988E+03	1.008E+04	1.007E+04	8.726E+03	8.719E+03
24	1.472E+01	5.004E+03	4.996E+03	1.005E+04	1.004E+04	8.700E+03	8.698E+03
25	1.536E+01	5.001E+03	4.999E+03	1.002E+04	1.002E+04	8.676E+03	8.676E+03

HOT SKIRT PROBLEM NUMBER 22
CYLINDER NUMBER 1

INPUT DATA**********

NUMBER OF INCREMENTS 25 MINIMUM X .000E-01 INCHES MAXIMUM X 1.600E+01 INCHES
MOMENT APPLIED TO JUNCTION .000E-01 INCH POUNDS
SHEAR LOAD APPLIED TO JUNCTION .000E-01 POUNDS
CYLINDER SLOTTED FROM X= .000E-01 TO X= .000E-01
FRACTION OF MAXIMUM DISTORTION USED AS CONVERGENCE CRITERION 1.00E-02
EXPONENT 10
MINIMUM CONVERGENCE FRACTION 6.00E-02

CYLINDER PARAMETERS

STA NO	X LOCATION	YOUNGS MODULUS	RADIUS	POISSONS RATIO	WALL THICKNESS	THERMAL COEFF	MEDIAN TEMP	RADIAL TEMP DIFF	AXIAL LOAD
1	.000E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
26	1.600E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01

NUMBER OF ITERATIONS 1
NUMBER OF ITERATIONS 23
NUMBER OF ITERATIONS 23

HOT SKIRT PROBLEM NUMBER 22
CYLINDER NUMBER 2

INPUT DATA**********

NUMBER OF INCREMENTS 25 MINIMUM X .000E-01 INCHES MAXIMUM X 1.600E+01 INCHES
MOMENT APPLIED TO JUNCTION .000E-01 INCH POUNDS
SHEAR LOAD APPLIED TO JUNCTION .000E-01 POUNDS
CYLINDER SLOTTED FROM X= .000E-01 TO X= .000E-01
FRACTION OF MAXIMUM DISTORTION USED AS CONVERGENCE CRITERION 1.00E-02
EXPONENT 10
MINIMUM CONVERGENCE FRACTION 6.00E-02
R1= 5.000E+01, R2= 5.000E+01

CYLINDER PARAMETERS

STA NO	X LOCATION	YOUNGS MODULUS	RADIUS	POISSONS RATIO	WALL THICKNESS	THERMAL COEFF	MEDIAN TEMP	RADIAL TEMP DIFF	AXIAL LOAD
1	.000E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
26	1.600E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01

NUMBER OF ITERATIONS 1
NUMBER OF ITERATIONS 23
NUMBER OF ITERATIONS 23

HOT SKIRT PROBLEM NUMBER 22
CYLINDER NUMBER 3

INPUT DATA**********

NUMBER OF INCREMENTS 25 MINIMUM X .000E-01 INCHES MAXIMUM X 1.600E+01 INCHES
MOMENT APPLIED TO JUNCTION .000E-01 INCH POUNDS
SHEAR LOAD APPLIED TO JUNCTION .000E-01 POUNDS
CYLINDER SLOTTED FROM X= .000E-01 TO X= .000E-01
FRACTION OF MAXIMUM DISTORTION USED AS CONVERGENCE CRITERION 1.00E-02
EXPONENT 10
MINIMUM CONVERGENCE FRACTION 6.00E-02
R1 IS INFINITE, R2= 5.000E+01

CYLINDER PARAMETERS

STA NO	X LOCATION	YOUNGS MODULUS	RADIUS	POISSONS RATIO	WALL THICKNESS	THERMAL COEFF	MEDIAN TEMP	RADIAL TEMP DIFF	AXIAL LOAD
1	.000E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
26	1.600E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01

NUMBER OF ITERATIONS 1
NUMBER OF ITERATIONS 23
NUMBER OF ITERATIONS 23

PROBLEM NUMBER 22

RESULTS FOR CYLINDER NUMBER 1

MAXIMUM DISTORTION ENERGY STRESS OF 5.427E+03 PSI, OCCURS AT STATION NUMBER 1, X= .000E-01
ON INNER SURFACE OF SHELL.

RESULTS FOR CYLINDER NUMBER 2

MAXIMUM DISTORTION ENERGY STRESS OF 8.142E+03 PSI, OCCURS AT STATION NUMBER 1, X= .000E-01
ON INNER SURFACE OF SHELL.

RESULTS FOR CYLINDER NUMBER 3

MAXIMUM DISTORTION ENERGY STRESS OF 9.019E+03 PSI, OCCURS AT STATION NUMBER 13, X= 7.680E+00
ON OUTER SURFACE OF SHELL.

HOT SKIRT PROBLEM NUMBER 80
CYLINDER NUMBER 1

INPUT DATA**********

NUMBER OF INCREMENTS 25 MINIMUM X .000E-01 INCHES MAXIMUM X 1.600E+01 INCHES
MOMENT APPLIED TO JUNCTION 5.000E+02 INCH POUNDS
SHEAR LOAD APPLIED TO JUNCTION 5.000E+02 POUNDS
CYLINDER SLOTTED FROM X= .000E-01 TO X= 1.000E+01
FRACTION OF MAXIMUM DISTORTION USED AS CONVERGENCE CRITERION 1.000E-02
EXPONENT 10
MINIMUM CONVERGENCE FRACTION 6.00E-02

CYLINDER PARAMETERS

STA NO	X LOCATION	YOUNGS MODULUS	RADIUS	POISSONS RATIO	WALL THICKNESS	THERMAL COEFF	MEDIAN TEMP	RADIAL TEMP DIFF	AXIAL LOAD
1	.000E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.000E+02	.000E-01	-5.000E+03
2	6.400E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	2.938E+02	.000E-01	-5.031E+03
3	1.280E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	2.876E+02	.000E-01	-5.061E+03
4	1.920E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	2.813E+02	.000E-01	-5.091E+03
5	2.560E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	2.751E+02	.000E-01	-5.122E+03
6	3.200E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	2.688E+02	.000E-01	-5.152E+03
7	3.840E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	2.632E+02	.000E-01	-5.182E+03
8	4.480E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	2.576E+02	.000E-01	-5.213E+03
9	5.120E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	2.520E+02	.000E-01	-5.243E+03
10	5.760E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	2.464E+02	.000E-01	-5.273E+03
11	6.400E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	2.411E+02	.000E-01	-5.303E+03
12	7.040E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	2.358E+02	.000E-01	-5.334E+03
13	7.680E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	2.306E+02	.000E-01	-5.364E+03
14	8.320E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	2.253E+02	.000E-01	-5.395E+03
15	8.960E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	2.200E+02	.000E-01	-5.425E+03
16	9.600E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	2.153E+02	.000E-01	-5.455E+03
17	1.024E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	2.105E+02	.000E-01	-5.486E+03
18	1.088E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	2.058E+02	.000E-01	-5.516E+03
19	1.152E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	2.011E+02	.000E-01	-5.547E+03
20	1.216E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	1.964E+02	.000E-01	-5.577E+03
21	1.280E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	1.916E+02	.000E-01	-5.608E+03
22	1.344E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	1.869E+02	.000E-01	-5.638E+03
23	1.408E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	1.822E+02	.000E-01	-5.669E+03
24	1.472E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	1.775E+02	.000E-01	-5.699E+03
25	1.536E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	1.727E+02	.000E-01	-5.730E+03
26	1.600E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	1.680E+02	.000E-01	-5.760E+03

NUMBER OF ITERATIONS 11
NUMBER OF ITERATIONS 23

HOT SKIRT PROBLEM NUMBER 80
CYLINDER NUMBER 2

INPUT DATA**********

NUMBER OF INCREMENTS 25 MINIMUM X .000E-01 INCHES MAXIMUM X 1.600E+01 INCHES
MOMENT APPLIED TO JUNCTION 5.000E+02 INCH POUNDS
SHEAR LOAD APPLIED TO JUNCTION 5.000E+02 POUNDS
CYLINDER SLOTTED FROM X= .000E-01 TO X= .000E-01
FRACTION OF MAXIMUM DISTORTION USED AS CONVERGENCE CRITERION 1.00E-02
EXPONENT 10
MINIMUM CONVERGENCE FRACTION 6.00E-02
R1= 5.000E+01, R2= 5.00CE+01

CYLINDER PARAMETERS

STA NO	X LOCATION	YOUNGS MODULUS	RADIUS	POISSONS RATIO	WALL THICKNESS	THERMAL COEFF	MEDIAN TEMP	RADIAL TEMP DIFF	AXIAL LOAD
1	.000E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.000E+02	2.500E+01	3.500E+03
2	6.400E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.031E+02	2.533E+01	3.470E+03
3	1.280E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.062E+02	2.570E+01	3.439E+03
4	1.920E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.093E+02	2.590E+01	3.409E+03
5	2.560E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.125E+02	2.610E+01	3.378E+03
6	3.200E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.156E+02	2.630E+01	3.348E+03
7	3.840E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.184E+02	2.652E+01	3.318E+03
8	4.480E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.212E+02	2.675E+01	3.288E+03
9	5.120E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.240E+02	2.697E+01	3.257E+03
10	5.760E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.268E+02	2.720E+01	3.227E+03
11	6.400E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.294E+02	2.744E+01	3.197E+03
12	7.040E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.321E+02	2.768E+01	3.166E+03
13	7.680E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.347E+02	2.792E+01	3.136E+03
14	8.320E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.374E+02	2.816E+01	3.105E+03
15	8.960E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.400E+02	2.840E+01	3.075E+03
16	9.600E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.424E+02	2.859E+01	3.045E+03
17	1.024E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.447E+02	2.878E+01	3.014E+03
18	1.088E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.471E+02	2.897E+01	2.984E+03
19	1.152E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.495E+02	2.916E+01	2.953E+03
20	1.216E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.518E+02	2.935E+01	2.923E+03
21	1.280E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.542E+02	2.955E+01	2.892E+03
22	1.344E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.565E+02	2.974E+01	2.862E+03
23	1.408E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.589E+02	2.993E+01	2.831E+03
24	1.472E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.613E+02	3.012E+01	2.801E+03
25	1.536E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.636E+02	3.031E+01	2.770E+03
26	1.600E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.660E+02	3.050E+01	2.740E+03

NUMBER OF ITERATIONS 23
NUMBER OF ITERATIONS 23
NUMBER OF ITERATIONS 24

HOT SKIRT PROBLEM NUMBER 80
CYLINDER NUMBER 3

INPUT DATA**********

NUMBER OF INCREMENTS 25 MINIMUM X .000E-01 INCHES MAXIMUM X 1.600E+01 INCHES
MOMENT APPLIED TO JUNCTION 5.000E+02 INCH POUNDS
SHEAR LOAD APPLIED TO JUNCTION 5.000E+02 POUNDS
CYLINDER SLOTTED FROM X= .000E-01 TO X= .000E-01
FRACTION OF MAXIMUM DISTORTION USED AS CONVERGENCE CRITERION 1.00E-02
EXPONENT 10
MINIMUM CONVERGENCE FRACTION 6.00E-02
R1 IS INFINITE, R2= 5.000E+01

CYLINDER PARAMETERS

STA NO	X LOCATION	YOUNGS MODULUS	RADIUS	POISSONS RATIO	WALL THICKNESS	THERMAL COEFF	MEDIAN TEMP	RADIAL TEMP DIFF	AXIAL LOAD
1	.000E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.000E+02	2.500E+01	-1.500E+03
2	6.400E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.031E+02	2.535E+01	-1.470E+03
3	1.280E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.062E+02	2.570E+01	-1.439E+03
4	1.920E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	3.093E+02	2.620E+01	-1.408E+03
5	2.560E+00	3.000E+07	5.000E+01	3.000E-01	4.500E-01	7.700E-06	3.125E+02	2.670E+01	-1.377E+03
6	3.200E+00	3.000E+07	5.000E+01	3.000E-01	4.500E-01	7.700E-06	3.156E+02	2.720E+01	-1.346E+03
7	3.840E+00	3.000E+07	5.000E+01	3.000E-01	4.500E-01	7.700E-06	3.184E+02	2.720E+01	-1.316E+03
8	4.480E+00	3.000E+07	5.000E+01	3.000E-01	4.500E-01	7.700E-06	3.212E+02	2.720E+01	-1.287E+03
9	5.120E+00	3.000E+07	5.000E+01	3.000E-01	4.500E-01	7.700E-06	3.240E+02	2.720E+01	-1.257E+03
10	5.760E+00	3.000E+07	5.000E+01	3.000E-01	4.000E-01	7.700E-06	3.268E+02	2.720E+01	-1.227E+03
11	6.400E+00	3.000E+07	5.000E+01	3.000E-01	4.000E-01	7.700E-06	3.294E+02	2.744E+01	-1.197E+03
12	7.040E+00	3.000E+07	5.000E+01	3.000E-01	4.000E-01	7.700E-06	3.321E+02	2.768E+01	-1.166E+03
13	7.680E+00	3.000E+07	5.000E+01	3.000E-01	4.000E-01	7.700E-06	3.347E+02	2.792E+01	-1.136E+03
14	8.320E+00	3.000E+07	5.000E+01	3.000E-01	4.000E-01	7.700E-06	3.374E+02	2.816E+01	-1.105E+03
15	8.960E+00	3.000E+07	5.000E+01	3.000E-01	3.500E-01	7.700E-06	3.400E+02	2.840E+01	-1.075E+03
16	9.600E+00	3.000E+07	5.000E+01	3.000E-01	3.500E-01	7.700E-06	3.424E+02	2.859E+01	-1.045E+03
17	1.024E+01	3.000E+07	5.000E+01	3.000E-01	3.500E-01	7.700E-06	3.447E+02	2.878E+01	-1.014E+03
18	1.088E+01	3.000E+07	5.000E+01	3.000E-01	3.500E-01	7.700E-06	3.471E+02	2.897E+01	-9.836E+02
19	1.152E+01	3.000E+07	5.000E+01	3.000E-01	3.500E-01	7.700E-06	3.495E+02	2.916E+01	-9.532E+02
20	1.216E+01	3.000E+07	5.000E+01	3.000E-01	3.000E-01	7.700E-06	3.518E+02	2.935E+01	-9.227E+02
21	1.280E+01	3.000E+07	5.000E+01	3.000E-01	3.000E-01	7.700E-06	3.542E+02	2.955E+01	-8.923E+02
22	1.344E+01	3.000E+07	5.000E+01	3.000E-01	3.000E-01	7.700E-06	3.565E+02	2.974E+01	-8.618E+02
23	1.408E+01	3.000E+07	5.000E+01	3.000E-01	3.000E-01	7.700E-06	3.589E+02	2.993E+01	-8.314E+02
24	1.472E+01	3.000E+07	5.000E+01	3.000E-01	3.000E-01	7.700E-06	3.613E+02	3.012E+01	-8.009E+02
25	1.536E+01	3.000E+07	5.000E+01	3.000E-01	2.500E-01	7.700E-06	3.636E+02	3.031E+01	-7.705E+02
26	1.600E+01	3.000E+07	5.000E+01	3.000E-01	2.500E-01	7.700E-06	3.660E+02	3.050E+01	-7.400E+02

NUMBER OF ITERATIONS 21
NUMBER OF ITERATIONS 20
NUMBER OF ITERATIONS 21

PROBLEM NUMBER 80

RESULTS FOR CYLINDER NUMBER 1

STA NO	X LOCATION	OUTER STRESS LONGITUDINAL	INNER STRESS LONGITUDINAL	OUTER STRESS CIRCUMFERENTIAL	INNER STRESS CIRCUMFERENTIAL	MOMENT	SHEAR
1	.000E-01	3.235E+03	-3.298E+03	1.371E+04	1.175E+04	-1.361E+02	5.302E+01
2	6.400E-01	2.889E+03	-2.953E+03	8.764E+02	-8.764E+02	-1.217E+02	2.248E+01
3	1.280E+00	2.544E+03	-2.608E+03	7.728E+02	-7.728E+02	-1.073E+02	2.248E+01
4	1.920E+00	2.198E+03	-2.263E+03	6.692E+02	-6.692E+02	-9.295E+01	2.248E+01
5	2.560E+00	1.853E+03	-1.918E+03	5.657E+02	-5.657E+02	-7.856E+01	2.248E+01
6	3.200E+00	1.507E+03	-1.573E+03	4.621E+02	-4.621E+02	-6.418E+01	2.248E+01
7	3.840E+00	1.162E+03	-1.228E+03	3.585E+02	-3.585E+02	-4.979E+01	2.248E+01
8	4.480E+00	8.166E+02	-8.829E+02	2.549E+02	-2.549E+02	-3.541E+01	2.248E+01
9	5.120E+00	4.711E+02	-5.378E+02	1.513E+02	-1.513E+02	-2.102E+01	2.248E+01
10	5.760E+00	1.256E+02	-1.928E+02	4.776E+01	-4.776E+01	-6.633E+00	2.248E+01
11	6.400E+00	-2.198E+02	1.523E+02	-5.582E+01	5.582E+01	7.753E+00	2.248E+01
12	7.040E+00	-5.653E+02	4.974E+02	-1.594E+02	1.594E+02	2.214E+01	2.248E+01
13	7.680E+00	-9.108E+02	8.425E+02	-2.630E+02	2.630E+02	3.653E+01	2.248E+01
14	8.320E+00	-1.256E+03	1.188E+03	-3.666E+02	3.666E+02	5.091E+01	2.248E+01
15	8.960E+00	-1.602E+03	1.533E+03	-4.701E+02	4.701E+02	6.530E+01	2.248E+01
16	9.600E+00	-1.947E+03	1.878E+03	-5.737E+02	5.737E+02	7.968E+01	2.248E+01
17	1.024E+01	-2.293E+03	2.223E+03	1.862E+03	3.217E+03	9.407E+01	1.326E+01
18	1.088E+01	-2.355E+03	2.285E+03	1.142E+03	2.534E+03	9.666E+01	-2.870E+00
19	1.152E+01	-2.205E+03	2.134E+03	5.548E+02	1.857E+03	9.040E+01	-1.459E+01
20	1.216E+01	-1.907E+03	1.836E+03	7.656E+01	1.200E+03	7.799E+01	-2.227E+01
21	1.280E+01	-1.521E+03	1.450E+03	-3.193E+02	5.719E+02	6.189E+01	-2.628E+01
22	1.344E+01	-1.100E+03	1.029E+03	-6.606E+02	-2.188E+01	4.435E+01	-2.69CE+01
23	1.408E+01	-6.952E+02	6.230E+02	-9.747E+02	-5.793E+02	2.746E+01	-2.435E+01
24	1.472E+01	-3.527E+02	2.801E+02	-1.288E+03	-1.098E+03	1.318E+01	-1.879E+01
25	1.536E+01	-1.184E+02	4.540E+01	-1.624E+03	-1.575E+03	3.412E+00	-1.03CE+01

PROBLEM NUMBER 80

RESULTS FOR CYLINDER NUMBER 2

STA NO	X LOCATION	OUTER STRESS LONGITUDINAL	INNER STRESS LONGITUDINAL	OUTER STRESS CIRCUMFERENTIAL	INNER STRESS CIRCUMFERENTIAL	MOMENT	SHEAR
1	.000E-01	3.175E+03	6.869E+03	1.727E+04	1.260E+04	7.696E+01	-2.347E+01
2	6.400E-01	9.091E+02	9.135E+03	1.442E+04	1.103E+04	1.714E+02	-7.849E+01
3	1.280E+00	-5.909E+02	1.063E+04	1.205E+04	9.483E+03	2.339E+02	-1.223E+02
4	1.920E+00	-1.884E+02	1.023E+04	1.052E+04	7.666E+03	2.171E+02	-1.547E+02
5	2.560E+00	6.313E+02	9.412E+03	9.402E+03	6.007E+03	1.829E+02	-1.775E+02
6	3.200E+00	1.733E+03	8.310E+03	8.625E+03	4.523E+03	1.370E+02	-1.922E+02
7	3.840E+00	2.784E+03	7.258E+03	8.141E+03	3.355E+03	9.319E+01	-2.006E+02
8	4.480E+00	3.925E+03	6.117E+03	7.880E+03	2.358E+03	4.568E+01	-2.043E+02
9	5.120E+00	5.090E+03	4.952E+03	7.791E+03	1.518E+03	-2.881E+00	-2.044E+02
10	5.760E+00	6.233E+03	3.808E+03	7.826E+03	8.153E+02	-5.051E+01	-2.018E+02
11	6.400E+00	7.186E+03	2.855E+03	7.940E+03	3.023E+02	-9.023E+01	-1.974E+02
12	7.040E+00	8.060E+03	1.980E+03	8.101E+03	-1.166E+02	-1.267E+02	-1.918E+02
13	7.680E+00	8.841E+03	1.199E+03	8.280E+03	-4.619E+02	-1.592E+02	-1.854E+02
14	8.320E+00	9.519E+03	5.205E+02	8.452E+03	-7.529E+02	-1.875E+02	-1.784E+02
15	8.960E+00	1.009E+04	-4.743E+01	8.594E+03	-1.006E+03	-2.111E+02	-1.710E+02
16	9.600E+00	1.097E+04	-9.317E+02	8.878E+03	-1.297E+03	-2.480E+02	-1.634E+02
17	1.024E+01	1.174E+04	-1.698E+03	9.090E+03	-1.588E+03	-2.799E+02	-1.555E+02
18	1.088E+01	1.238E+04	-2.341E+03	9.207E+03	-1.902E+03	-3.067E+02	-1.472E+02
19	1.152E+01	1.289E+04	-2.851E+03	9.206E+03	-2.252E+03	-3.279E+02	-1.379E+02
20	1.216E+01	1.325E+04	-3.210E+03	9.070E+03	-2.648E+03	-3.428E+02	-1.272E+02
21	1.280E+01	1.343E+04	-3.391E+03	8.778E+03	-3.092E+03	-3.504E+02	-1.145E+02
22	1.344E+01	1.339E+04	-3.358E+03	8.318E+03	-3.577E+03	-3.490E+02	-9.906E+01
23	1.408E+01	1.310E+04	-3.065E+03	7.675E+03	-4.087E+03	-3.368E+02	-8.027E+01
24	1.472E+01	1.249E+04	-2.455E+03	6.844E+03	-4.597E+03	-3.114E+02	-5.750E+01
25	1.536E+01	1.150E+04	-1.462E+03	5.824E+03	-5.066E+03	-2.700E+02	-3.025E+01

PROBLEM NUMBER 80

RESULTS FOR CYLINDER NUMBER 3

STA NO	X LOCATION	OUTER STRESS LONGITUDINAL	INNER STRESS LONGITUDINAL	OUTER STRESS CIRCUMFERENTIAL	INNER STRESS CIRCUMFERENTIAL	MOMENT	SHEAR
1	.000E-01	1.841E+04	-8.429E+03	2.184E+04	8.009E+03	-5.592E+02	4.705E+02
2	6.400E-01	1.656E+04	-6.578E+03	2.206E+04	9.264E+03	-4.820E+02	4.353E+02
3	1.280E+00	1.528E+04	-5.300E+03	2.224E+04	1.013E+04	-4.288E+02	3.959E+02
4	1.920E+00	1.684E+04	-6.855E+03	2.309E+04	9.934E+03	-4.936E+02	3.530E+02
5	2.560E+00	2.020E+04	-9.109E+03	2.521E+04	1.025E+04	-4.946E+02	3.103E+02
6	3.200E+00	2.202E+04	-1.093E+04	2.558E+04	9.416E+03	-5.561E+02	2.700E+02
7	3.840E+00	1.728E+04	-6.187E+03	2.361E+04	1.029E+04	-3.960E+02	2.319E+02
8	4.480E+00	1.323E+04	-2.133E+03	2.160E+04	1.071E+04	-2.592E+02	1.981E+02
9	5.120E+00	9.768E+03	1.325E+03	1.967E+04	1.085E+04	-1.425E+02	1.695E+02
10	5.760E+00	6.632E+03	5.848E+03	1.902E+04	1.250E+04	-1.045E+01	1.477E+02
11	6.400E+00	6.815E+03	5.666E+03	1.840E+04	1.172E+04	-1.532E+01	1.318E+02
12	7.040E+00	7.331E+03	5.151E+03	1.803E+04	1.098E+04	-2.907E+01	1.195E+02
13	7.680E+00	8.104E+03	4.378E+03	1.787E+04	1.030E+04	-4.969E+01	1.100E+02
14	8.320E+00	9.078E+03	3.405E+03	1.787E+04	9.659E+03	-7.564E+01	1.026E+02
15	8.960E+00	9.815E+03	4.451E+03	1.938E+04	1.121E+04	-5.477E+01	9.705E+01
16	9.600E+00	9.638E+03	4.629E+03	1.924E+04	1.114E+04	-5.114E+01	9.282E+01
17	1.024E+01	9.585E+03	4.682E+03	1.924E+04	1.112E+04	-5.005E+01	8.887E+01
18	1.088E+01	9.655E+03	4.613E+03	1.937E+04	1.117E+04	-5.148E+01	8.474E+01
19	1.152E+01	9.861E+03	4.407E+03	1.964E+04	1.127E+04	-5.568E+01	7.999E+01
20	1.216E+01	9.789E+03	6.858E+03	2.194E+04	1.428E+04	-2.198E+01	7.466E+01
21	1.280E+01	9.515E+03	7.133E+03	2.232E+04	1.478E+04	-1.786E+01	6.834E+01
22	1.344E+01	9.546E+03	7.102E+03	2.297E+04	1.537E+04	-1.833E+01	5.999E+01
23	1.408E+01	9.984E+03	6.665E+03	2.394E+04	1.603E+04	-2.490E+01	4.890E+01
24	1.472E+01	1.096E+04	5.687E+03	2.522E+04	1.668E+04	-3.956E+01	3.439E+01
25	1.536E+01	1.279E+04	7.195E+03	2.971E+04	2.103E+04	-2.912E+01	1.763E+01

HOT SKIRT PROBLEM NUMBER 90
CYLINDER NUMBER 1

INPUT DATA**********

NUMBER OF INCREMENTS 25 MINIMUM X .000E-01 INCHES MAXIMUM X 1.000E-07 INCHES
MOMENT APPLIED TO JUNCTION .000E-01 INCH POUNDS
SHEAR LOAD APPLIED TO JUNCTION .000E-01 POUNDS
CYLINDER SLOTTED FROM X= .000E-01 TO X= .000E-01
FRACTION OF MAXIMUM DISTORTION USED AS CONVERGENCE CRITERION 1.00E-02
EXPONENT 10
MINIMUM CONVERGENCE FRACTION 6.00E-02

CYLINDER PARAMETERS

STA NO	X LOCATION	YOUNGS MODULUS	RADIUS	POISSONS RATIO	WALL THICKNESS	THERMAL COEFF	MEDIAN TEMP	RADIAL TEMP DIFF	AXIAL LOAD
1	.000E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
2	4.000E-09	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
3	8.000E-09	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
4	1.200E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
5	1.600E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
6	2.000E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
7	2.400E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
8	2.800E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
9	3.200E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
10	3.600E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
11	4.000E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
12	4.400E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
13	4.800E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
14	5.200E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
15	5.600E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
16	6.000E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
17	6.400E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
18	6.800E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
19	7.200E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
20	7.600E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
21	8.000E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
22	8.400E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
23	8.800E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
24	9.200E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
25	9.600E-08	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
26	1.000E-07	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01

NUMBER OF ITERATIONS 1
NUMBER OF ITERATIONS 1
NUMBER OF ITERATIONS 1

HOT SKIRT PROBLEM NUMBER 90
CYLINDER NUMBER 2

INPUT DATA**********

NUMBER OF INCREMENTS 25 MINIMUM X .000E-01 INCHES MAXIMUM X 1.600E+01 INCHES
MOMENT APPLIED TO JUNCTION .000E-01 INCH POUNDS
SHEAR LOAD APPLIED TO JUNCTION .000E-01 POUNDS
CYLINDER SLOTTED FROM X= .000E-01 TO X= .000E-01
FRACTION OF MAXIMUM DISTORTION USED AS CONVERGENCE CRITERION 1.00E-02
EXPONENT 10
MINIMUM CONVERGENCE FRACTION 6.00E-02
R1= 5.000E+01, R2= 5.000E+01

CYLINDER PARAMETERS

STA NO	X LOCATION	YOUNGS MODULUS	RADIUS	POISSONS RATIO	WALL THICKNESS	THERMAL COEFF	MEDIAN TEMP	RADIAL TEMP DIFF	AXIAL LOAD
1	.000E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
2	6.400E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
3	1.280E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
4	1.920E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
5	2.560E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
6	3.200E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
7	3.840E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
8	4.480E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
9	5.120E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
10	5.760E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
11	6.400E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
12	7.040E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
13	7.680E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
14	8.320E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
15	8.960E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
16	9.600E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
17	1.024E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
18	1.088E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
19	1.152E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
20	1.216E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
21	1.280E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
22	1.344E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
23	1.408E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
24	1.472E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
25	1.536E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
26	1.600E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01

NUMBER OF ITERATIONS 1
NUMBER OF ITERATIONS 23
NUMBER OF ITERATIONS 23

HOT SKIRT PROBLEM NUMBER 90
CYLINDER NUMBER 3

INPUT DATA...

NUMBER OF INCREMENTS 25   MINIMUM X   .000E-01 INCHES   MAXIMUM X 1.600E+01 INCHES
MOMENT APPLIED TO JUNCTION   .000E-01 INCH POUNDS
SHEAR LOAD APPLIED TO JUNCTION   .000E-01 POUNDS
CYLINDER SLOTTED FROM X=   .000E-01 TO X=   .000E-01
FRACTION OF MAXIMUM DISTORTION USED AS CONVERGENCE CRITERION 1.00E-02
EXPONENT 10
MINIMUM CONVERGENCE FRACTION 6.00E-02
R1 IS INFINITE, R2= 5.000E+01

CYLINDER PARAMETERS

STA NO	X LOCATION	YOUNGS MODULUS	RADIUS	POISSONS RATIO	WALL THICKNESS	THERMAL COEFF	MEDIAN TEMP	RADIAL TEMP DIFF	AXIAL LOAD
1	.000E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
2	6.400E-01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
3	1.280E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
4	1.920E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
5	2.560E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
6	3.200E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
7	3.840E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
8	4.480E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
9	5.120E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
10	5.760E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
11	6.400E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
12	7.040E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
13	7.680E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
14	8.320E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
15	8.960E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
16	9.600E+00	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
17	1.024E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
18	1.088E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
19	1.152E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
20	1.216E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
21	1.280E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
22	1.344E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
23	1.408E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
24	1.472E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
25	1.536E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01
26	1.600E+01	3.000E+07	5.000E+01	3.000E-01	5.000E-01	7.700E-06	.000E-01	.000E-01	.000E-01

NUMBER OF ITERATIONS   1
NUMBER OF ITERATIONS 23
NUMBER OF ITERATIONS 23

PROBLEM NUMBER 90

RESULTS FOR CYLINDER NUMBER 1

STA NO	X LOCATION	OUTER STRESS LONGITUDINAL	INNER STRESS LONGITUDINAL	OUTER STRESS CIRCUMFERENTIAL	INNER STRESS CIRCUMFERENTIAL	MOMENT	SHEAR
1	.000E-01	7.200E-12	-7.200E-12	6.000E+03	6.000E+03	-3.000E-13	6.000E-06
2	4.000E-09	6.636E-12	-6.636E-12	6.000E+03	6.000E+03	-2.765E-13	5.760E-06
3	8.000E-09	6.094E-12	-6.094E-12	6.000E+03	6.000E+03	-2.539E-13	5.520E-06
4	1.200E-08	5.576E-12	-5.576E-12	6.000E+03	6.000E+03	-2.323E-13	5.280E-06
5	1.600E-08	5.080E-12	-5.080E-12	6.000E+03	6.000E+03	-2.117E-13	5.040E-06
6	2.000E-08	4.608E-12	-4.608E-12	6.000E+03	6.000E+03	-1.920E-13	4.800E-06
7	2.400E-08	4.159E-12	-4.159E-12	6.000E+03	6.000E+03	-1.733E-13	4.560E-06
8	2.800E-08	3.732E-12	-3.732E-12	6.000E+03	6.000E+03	-1.555E-13	4.320E-06
9	3.200E-08	3.329E-12	-3.329E-12	6.000E+03	6.000E+03	-1.387E-13	4.080E-06
10	3.600E-08	2.949E-12	-2.949E-12	6.000E+03	6.000E+03	-1.229E-13	3.840E-06
11	4.000E-08	2.592E-12	-2.592E-12	6.000E+03	6.000E+03	-1.080E-13	3.600E-06
12	4.400E-08	2.258E-12	-2.258E-12	6.000E+03	6.000E+03	-9.408E-14	3.360E-06
13	4.800E-08	1.947E-12	-1.947E-12	6.000E+03	6.000E+03	-8.112E-14	3.120E-06
14	5.200E-08	1.659E-12	-1.659E-12	6.000E+03	6.000E+03	-6.912E-14	2.880E-06
15	5.600E-08	1.394E-12	-1.394E-12	6.000E+03	6.000E+03	-5.808E-14	2.640E-06
16	6.000E-08	1.152E-12	-1.152E-12	6.000E+03	6.000E+03	-4.800E-14	2.400E-06
17	6.400E-08	9.331E-13	-9.331E-13	6.000E+03	6.000E+03	-3.888E-14	2.160E-06
18	6.800E-08	7.373E-13	-7.373E-13	6.000E+03	6.000E+03	-3.072E-14	1.920E-06
19	7.200E-08	5.645E-13	-5.645E-13	6.000E+03	6.000E+03	-2.352E-14	1.680E-06
20	7.600E-08	4.147E-13	-4.147E-13	6.000E+03	6.000E+03	-1.728E-14	1.440E-06
21	8.000E-08	2.880E-13	-2.880E-13	6.000E+03	6.000E+03	-1.200E-14	1.200E-06
22	8.400E-08	1.843E-13	-1.843E-13	6.000E+03	6.000E+03	-7.680E-15	9.600E-07
23	8.800E-08	1.037E-13	-1.037E-13	6.000E+03	6.000E+03	-4.320E-15	7.200E-07
24	9.200E-08	4.608E-14	-4.608E-14	6.000E+03	6.000E+03	-1.920E-15	4.800E-07
25	9.600E-08	1.152E-14	-1.152E-14	6.000E+03	6.000E+03	-4.800E-16	2.400E-07

PROBLEM NUMBER 90

RESULTS FOR CYLINDER NUMBER 2

STA NO	X LOCATION	OUTER STRESS LONGITUDINAL	INNER STRESS LONGITUDINAL	OUTER STRESS CIRCUMFERENTIAL	INNER STRESS CIRCUMFERENTIAL	MOMENT	SHEAR
1	.000E-01	5.000E+03	5.000E+03	7.500E+03	7.500E+03	5.808E-06	4.851E+01
2	6.400E-01	4.373E+03	5.627E+03	6.906E+03	7.282E+03	2.614E+01	3.414E+01
3	1.280E+00	3.951E+03	6.049E+03	6.392E+03	7.021E+03	4.371E+01	2.201E+01
4	1.920E+00	3.697E+03	6.303E+03	5.959E+03	6.741E+03	5.431E+01	1.227E+01
5	2.560E+00	3.574E+03	6.426E+03	5.605E+03	6.460E+03	5.941E+01	4.707E+00
6	3.200E+00	3.552E+03	6.448E+03	5.323E+03	6.192E+03	6.033E+01	-9.466E-01
7	3.840E+00	3.603E+03	6.397E+03	5.107E+03	5.945E+03	5.820E+01	-4.964E+00
8	4.480E+00	3.704E+03	6.296E+03	4.947E+03	5.725E+03	5.398E+01	-7.617E+00
9	5.120E+00	3.837E+03	6.163E+03	4.836E+03	5.533E+03	4.845E+01	-9.165E+00
10	5.760E+00	3.986E+03	6.014E+03	4.763E+03	5.372E+03	4.225E+01	-9.843E+00
11	6.400E+00	4.140E+03	5.860E+03	4.723E+03	5.239E+03	3.585E+01	-9.861E+00
12	7.040E+00	4.289E+03	5.711E+03	4.707E+03	5.134E+03	2.963E+01	-9.401E+00
13	7.680E+00	4.428E+03	5.572E+03	4.709E+03	5.052E+03	2.382E+01	-8.614E+00
14	8.320E+00	4.554E+03	5.446E+03	4.724E+03	4.992E+03	1.860E+01	-7.626E+00
15	8.960E+00	4.663E+03	5.337E+03	4.748E+03	4.950E+03	1.406E+01	-6.537E+00
16	9.600E+00	4.754E+03	5.246E+03	4.776E+03	4.923E+03	1.023E+01	-5.424E+00
17	1.024E+01	4.829E+03	5.171E+03	4.806E+03	4.909E+03	7.117E+00	-4.345E+00
18	1.088E+01	4.888E+03	5.112E+03	4.837E+03	4.904E+03	4.671E+00	-3.343E+00
19	1.152E+01	4.932E+03	5.068E+03	4.867E+03	4.908E+03	2.838E+00	-2.447E+00
20	1.216E+01	4.963E+03	5.037E+03	4.895E+03	4.917E+03	1.540E+00	-1.675E+00
21	1.280E+01	4.983E+03	5.017E+03	4.921E+03	4.931E+03	6.931E-01	-1.041E+00
22	1.344E+01	4.995E+03	5.005E+03	4.944E+03	4.947E+03	2.074E-01	-5.495E-01
23	1.408E+01	5.000E+03	5.000E+03	4.966E+03	4.966E+03	-1.035E-02	-2.046E-01
24	1.472E+01	5.001E+03	4.999E+03	4.987E+03	4.986E+03	-5.449E-02	-7.173E-03
25	1.536E+01	5.000E+03	5.000E+03	5.007E+03	5.006E+03	-1.953E-02	4.257E-02

PROBLEM NUMBER 90

RESULTS FOR CYLINDER NUMBER 3

STA NO	X LOCATION	OUTER STRESS LONGITUDINAL	INNER STRESS LONGITUDINAL	OUTER STRESS CIRCUMFERENTIAL	INNER STRESS CIRCUMFERENTIAL	MOMENT	SHEAR
1	.000E-01	5.000E+03	5.000E+03	7.500E+03	7.500E+03	5.808E-06	-4.851E+01
2	6.400E-01	5.627E+03	4.373E+03	8.094E+03	7.718E+03	-2.614E+01	-3.414E+01
3	1.280E+00	6.049E+03	3.951E+03	8.608E+03	7.979E+03	-4.371E+01	-2.201E+01
4	1.920E+00	6.303E+03	3.697E+03	9.041E+03	8.259E+03	-5.431E+01	-1.227E+01
5	2.560E+00	6.426E+03	3.574E+03	9.395E+03	8.540E+03	-5.941E+01	-4.707E+00
6	3.200E+00	6.448E+03	3.552E+03	9.677E+03	8.808E+03	-6.033E+01	9.466E-01
7	3.840E+00	6.397E+03	3.603E+03	9.893E+03	9.055E+03	-5.820E+01	4.964E+00
8	4.480E+00	6.296E+03	3.704E+03	1.005E+04	9.275E+03	-5.398E+01	7.617E+00
9	5.120E+00	6.163E+03	3.837E+03	1.016E+04	9.467E+03	-4.845E+01	9.165E+00
10	5.760E+00	6.014E+03	3.986E+03	1.024E+04	9.628E+03	-4.225E+01	9.843E+00
11	6.400E+00	5.860E+03	4.140E+03	1.028E+04	9.761E+03	-3.585E+01	9.861E+00
12	7.040E+00	5.711E+03	4.289E+03	1.029E+04	9.866E+03	-2.963E+01	9.401E+00
13	7.680E+00	5.572E+03	4.428E+03	1.029E+04	9.948E+03	-2.382E+01	8.614E+00
14	8.320E+00	5.446E+03	4.554E+03	1.028E+04	1.001E+04	-1.860E+01	7.626E+00
15	8.960E+00	5.337E+03	4.663E+03	1.025E+04	1.005E+04	-1.406E+01	6.537E+00
16	9.600E+00	5.246E+03	4.754E+03	1.022E+04	1.008E+04	-1.023E+01	5.424E+00
17	1.024E+01	5.171E+03	4.829E+03	1.019E+04	1.009E+04	-7.117E+00	4.345E+00
18	1.088E+01	5.112E+03	4.888E+03	1.016E+04	1.010E+04	-4.671E+00	3.343E+00
19	1.152E+01	5.068E+03	4.932E+03	1.013E+04	1.009E+04	-2.838E+00	2.447E+00
20	1.216E+01	5.037E+03	4.963E+03	1.011E+04	1.008E+04	-1.540E+00	1.675E+00
21	1.280E+01	5.017E+03	4.983E+03	1.008E+04	1.007E+04	-6.931E-01	1.041E+00
22	1.344E+01	5.005E+03	4.995E+03	1.006E+04	1.005E+04	-2.074E-01	5.495E-01
23	1.408E+01	5.000E+03	5.000E+03	1.003E+04	1.003E+04	1.035E-02	2.046E-01
24	1.472E+01	4.999E+03	5.001E+03	1.001E+04	1.001E+04	5.449E-02	7.173E-03
25	1.536E+01	5.000E+03	5.000E+03	9.993E+03	9.994E+03	1.953E-02	-4.257E-02

thesM2526
Thermal stress analysis of pressure vess
3 2768 002 04391 1
DUDLEY KNOX LIBRARY